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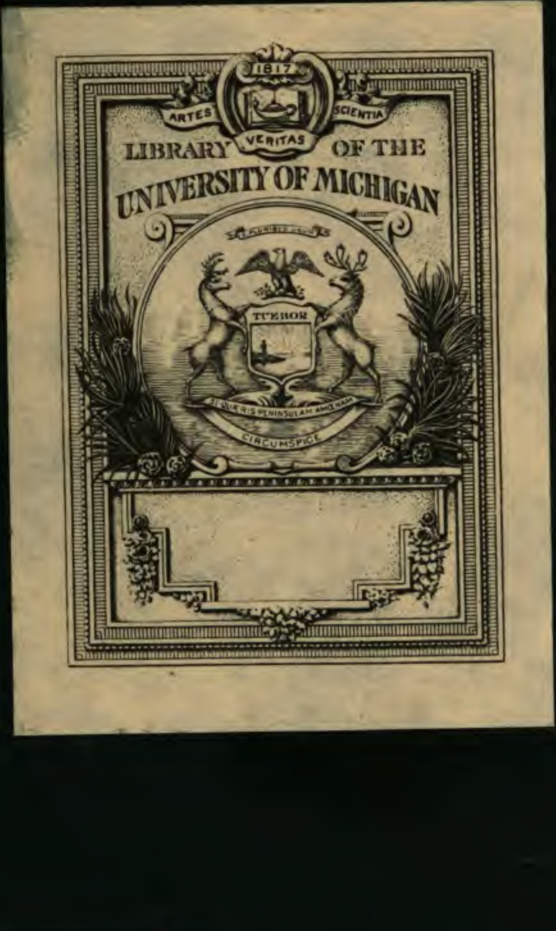

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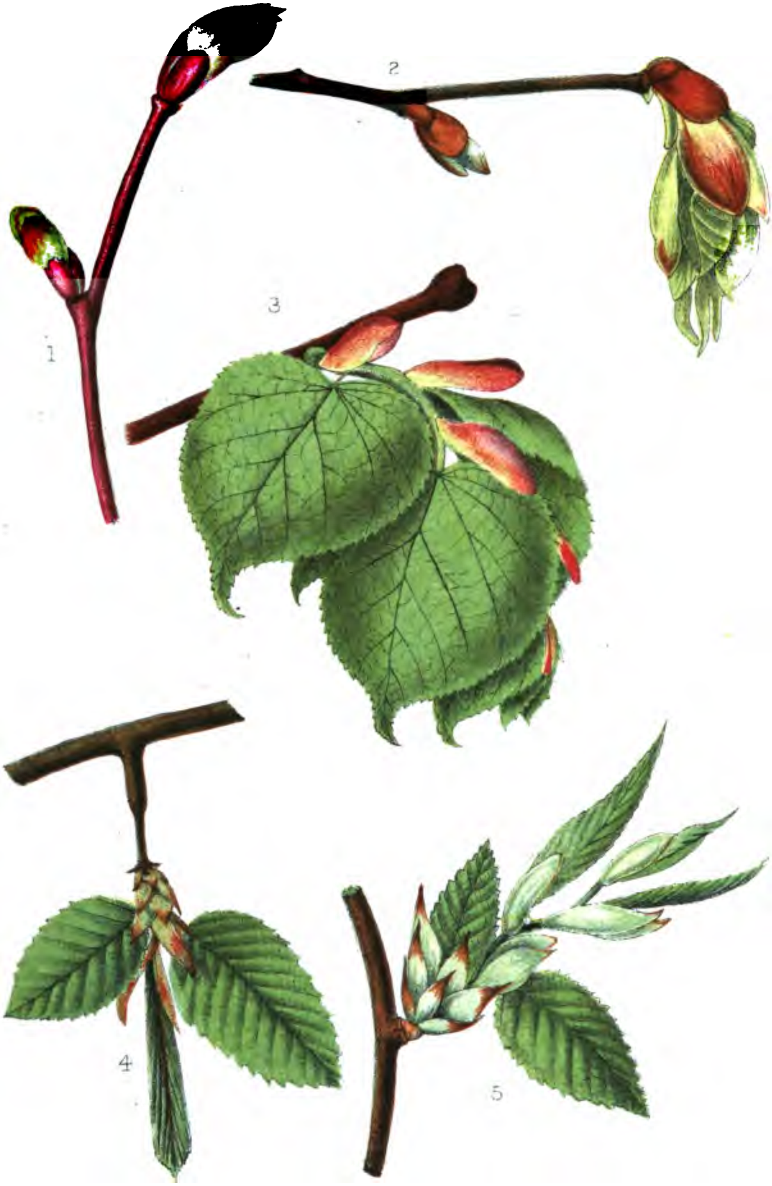

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PREFACE

VAUCHER long ago called attention to the fact that some species of Rock Rose have stipules while others have none, and suggested that it would be interesting, if possible, to ascertain the reason for this difference. The idea seemed to me a good one, and I devoted myself to a study of the question, with the result which will be found in the following pages.

This inquiry led me on to examine the structure of buds; and the diversity and ingenuity of the devices by which plants protect the young and tender tissues from heat, cold, drought, moisture, insects and other animals, proved so fascinating that I hoped it might not be without interest for others.

The results have been printed in greater detail by the Linnean Society,[1] and I have here selected those parts which seemed to me of most general interest.

I have to thank Mr. THISELTON DYER, the Director of Kew Gardens, Dr. SCOTT, and the whole staff, for the facilities they have kindly afforded me.

---

[1] 'On Stipules,' Parts i–iv. (*Linnean Society's Journal—Botany*, vols. xxviii, xxx, xxxiii), 1890, 1894, 1897.

The Trustees of the British Museum and Mr. MURRAY, the authorities of the Cambridge Botanic Gardens, and Mr. LYNCH, have also assisted me with many specimens.

Dr. RENDLE has been good enough again to help me by seeing the book through the press; and last, not least, I must cordially acknowledge how much I am indebted to my able assistant, Mr. FRASER, by whom also many of the drawings have been made.

JOHN LUBBOCK.

HIGH ELMS, DOWN, KENT:
December 30, 1898.

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BIBLIOGRAPHY

N.B.—*The numbers correspond with the references in the text.*

1. Potter, M. C. Observations on the Protection of Buds in the Tropics. *Journ. Linn. Soc.* (Bot.), xxviii. 343 (1891).
2. Vaucher, J. P. Sur la sève d'Août et sur les divers Modes de Développement des Arbres. *Soc. Phys. et Hist. Nat. Genève*, i. 296 (1822).
3. Tristan, J. Mémoire sur les Développements de Bourgeons. *Journ. de Physique*, 1813, 401.
4. Steinheil, Ad. Observations sur le Mode d'Accroissement des Feuilles. *Ann. Sci. Nat.* (ser. 2), viii. 257 (1837).
5. De Mercklin, C. E. Développement des Feuilles. *Ibid.* (ser. 3), vi. 215 (1846). (An abridged translation of his work, 'Zur Entwicklungs. d. Blättgestalten.' Jena, 1846.)
6. Trecul, A. Mémoire sur la Formation des Feuilles. *Ibid.* xx. 235 (1853).
7. Schacht, H. Anatomie und Physiologie, ii. (1854).
8. Eichler, A. Zur Entwicklungsgeschichtes des Blattes (1861).
9. Goebel, K. Beiträge zur Morphologie u. Physiologie des Blattes. *Botan. Zeit.* xxxviii. 753, &c. (1880).
10. Benjamin, L. Ueber intrapetiolare Knospenbildung. *Ibid.* x. 201, &c. (1852).
11. Naumann, A. Beiträge zur Entwicklungsgeschichte der Palmenblätter. *Flora*, lxx. 193, &c. (1887).
12. Grew, N. Anatomy of Plants, 32 (1672).
13. Feist, A. Ueber die Schutzeinrichtungen der Laubknospen dicotyler Laubbäume. *Nova Acta Acad. Caes. Leop.-Car.* li. 303 (1887).
14. Groom, P. On Bud-protection in Dicotyledons. *Trans. Linn. Soc.* (ser. 2, Bot.), iii. 255 (1893).

15. Hanstein, J. Ueber die Organe der Harz- u. Schleim-Absonderung in den Laubknospen. *Bot. Zeit.* xxvi. 697, &c. (1868).
16. Treub, M. Jets over Knopbedekking in de Tropen. *Handel. 1st. Nederl. Natuur- en Geneeskund. Congr.* 1887, 130. Abstract in *Botan. Centralbl.* xxxv. 328 (1888).
17. Ohlert, E. Einige Bemerkungen über die Knospen unserer Bäume und Sträucher. *Linnæa*, xi. 632 (1837).
18. Henry, A. Knospenbilder: ein Beiträg zur Kenntniss d. Laubknospen. *Nova Acta Acad. Caes.-Leop.*, xxii. 171 (1847).
19. Colomb, G. Recherches sur les Stipules. *Ann. Sci. Nat.* (ser. 7), vi. 1 (1887).
20. Bentham, G. Revision of the *Mimoseæ*. *Trans. Linn. Soc.* xxx. 341 (1875).
21. Belt, T. The Naturalist in Nicaragua, 218 (1874).
22. Bower, F. O. *Proc. Phil. Soc. Glasgow*, xviii. 320 (1887).
23. Schumann, K. in Engler and Prantl, Pflanzenfamilien, iv. pt. 4, 12 (1891).
24. Tyler, A. A. The Nature and Origin of Stipules. *Annals New York Acad. Sci.*, x.
25. Reincke, Fr. Ueber die Knospenlage der Laubblätter bei den Compositen, &c. Inaug. Dissert. Heidelberg, 1893.
26. Grevillius, A. Ueber die Stipelscheide einiger *Polygonum*-Arten. *Botan. Centralbl.* xxx. 254, &c. (1887)
27. Vines, S. H. Students' Text-book of Botany, 45 (1894).
28. Norman, J. Quelques Observations de Morphologie générale. *Ann. Sci. Nat.* (ser. 4) ix. 135 (1858).
29. Stenzel, G. Ueber Nebenblattbildungen. *Jahresb. Schles. Gesell. Vaterl. Cult.* (Breslau) lx. 224 (1882).
30. Cauvet, D. Probabilité de la présence des Stipules dans quelques Monocotylédones. *Bull. Soc. Bot. France*, xii. 241 (1865).
31. Van Tieghem, Ph. Traité de Botanique, 318 (1884).
32. Baillon, H. Recherches sur l'organisation &c., des Caprifoliacées. *Adansonia*, i. 372 (1861).
33. Gray, A. Structural Botany, 435 (1879).
34. Bentham, G. Handbook of the British Flora, 9 (1858).
35. Lindley, J. Introduction to Botany, 99 (1832).
36. Agardh, J. G. Om Växternas Stipler. *K. Vetensch. Akad. Handb.* 1849, 37 (1851).

37. Clos, D. Indépendance, développement, anomalies des Stipules. *Bull. Soc. Bot. France*, xxvi. 189 (1879).
38. —— Des Stipules et leur rôle dans l'Inflorescence et dans la Fleur. *Mém. Acad. Sci. Toulouse* (ser. 7), x. 201 (1878).
39. Turpin, P. J. F. Essai d'une Iconographie des Végétaux, 1820.
40. Kronfeld, M. Ueber die Beziehung der Nebenblätter zu ihren Hauptblättern. *Verhandl. Zool.-Bot. Gesell. Wien.* xxxvii. Abhandl. 69 (1887).
41. For further Information and Literature of the subject of Leaf-fall, see Rendle, A. B., 'Natural Science,' i. 680 (1892).

Detailed accounts of observations on the stipules of many genera and species, arranged under their families, will be found in the following papers:—

Lubbock, Sir J. On Stipules, their Form and Function. *Journ. Linn. Soc.* (Bot.) xxviii. 255 (1890), xxx. 463 (1894), and xxxiii. 202 (1897).

Were I a skilful painter,
  What should I paint for thee?
A tiny spring bud peeping out
  From a withered wintry tree.

G. MACDONALD.

BUDS AND STIPULES

CHAPTER I

ON BUDS

EVERYONE who loves a garden knows to his cost how susceptible young leaves are to cold—how often the bright promise of spring is ruined by late frosts. Buds offer also a tempting food to insects and other animals. Moreover, their development is generally a slow process, the buds for the following year being already formed, as a rule, during the previous summer, in many cases as early as June or July, and in some even a year and a half in advance. The protection of the buds is therefore one of the most important requisites in plant life—in cold countries against frost, in hot against the sun. During winter the young leaves lie snugly enclosed in several warm wraps, covered in many cases by furry hairs, and often still further protected from insects and browsing quadrupeds by gummy or resinous secretions.

The bud is a short shoot bearing a number of young leaves closely packed together. There is generally one at the summit of each twig and in the axil of each leaf.

When the year is divided into favourable and unfavourable seasons, marked either by alternations of temperature or by drought and rain, there is often a marked difference between 'growing' and 'resting' buds. Moreover, among our own species there is often a considerable difference between terminal and axillary buds, as, for instance, in the Black Poplar (*Populus nigra*).

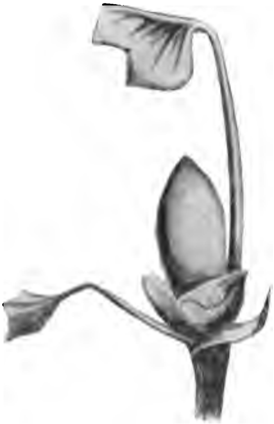

FIG. 1.—YOUNG SHOOT OF TULIP TREE (*Liriodendron*), 1½ nat. size.

The following figure (fig. 1), representing a young shoot of a Tulip Tree, is an illustration of the necessity for such protection. It will be seen that the outer (lower) leaf, which had only a single covering, has been killed by frost, while the succeeding one, which had two wraps, has escaped.

It is remarkable that some nearly allied genera, and even in certain cases species of the same genus, often differ in the method of the protection of the bud. This is the case, for instance, in the Willows and Poplars, the function being performed in the Poplars by stipules, in the Willows (though they possess stipules) by leaves.

The bud may either be protected by older organs, or its own outer envelopes may be modified for the purpose.

In some plants, especially those which are quick-growing or natives of tropical countries, the buds are comparatively naked and unprotected. Even in the tropics, however, though protection is not needed against cold, it is required against the burning sunlight and against drought.

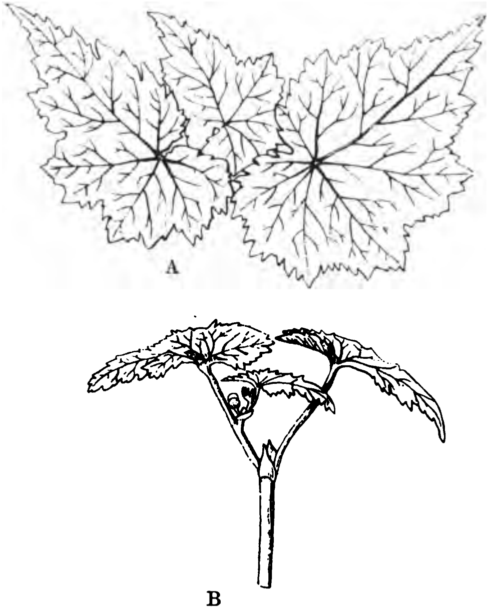

Fig. 2.—Begonia.
A, shoot seen from above. B, shoot seen from one side. Reduced.

In the Begonias (fig. 2), for instance, as Mr. Potter has pointed out (1),[1] the buds are shaded from the overpowering heat of the sun by the older leaves. Plants grown under artificial conditions do not show the arrangement well, as the leaves are often drawn to one side or the other by the light. But Mr. Potter, who has had the opportunity of examining many species in a wild state, found that they were always more or less arranged as shown in fig. 2.

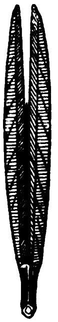

Fig. 3.

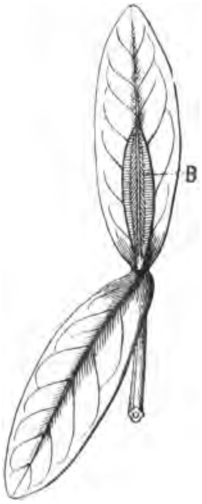

Fig. 4.

Young Leaves of Hypericum calycinum. Nat. size.

Fig. 3, seen from the side. Fig. 4, with one leaf turned back to show the younger, enclosed pair (B).

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[1] The works referred to by these numbers (1, &c.) are given in the 'Bibliography' at the end of the book.

The figure also shows how admirably the peculiar form of the leaf is adapted to their mode of growth. In many other plants also the leaves, as they develop, successively protect the younger ones.

A somewhat similar case is afforded by *Uvaria* (figs. 105, 106, p. 70); and also by common Rhubarb, where the delicate new leaves in the centre of the plant are protected by the large, horizontally spreading, older ones.

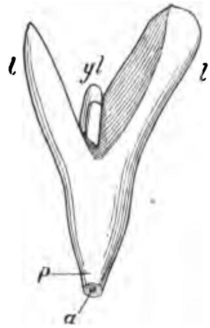


FIG. 5.—MESEMBRYANTHEMUM. *l, l*, pair of leaves, connate, and sheathing in their lower half; *p*, from this point to the base the leaves are attached to the axis, and axillary buds arise exactly at this place; *a*, axis; *yl*, next younger pair of leaves.

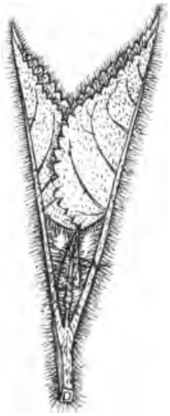


FIG. 6.—APEX OF SHOOT OF STACHYS SYLVATICA, showing two successive pairs of leaves. Nat. size.

Figs. 3 and 4 show the arrangement in one of the St. John's Worts (*Hypericum calycinum*). Each pair of opposite leaves is at first apposed by their edges, which touch all the way round, leaving between them an almond-shaped space, in which the next pair are enclosed; they in their turn surround the third, and so on.

Mesembryanthemum blandum has the leaves opposite, triquetrous, 3–5 cm. long, rounded on the dorsal edge, very shallowly grooved on the upper surface, more decidedly so at the base, and connate there, forming a sheath 3–5 cm. long, which remains green after the stem it encloses has become ripened and brown. The middle line of the sheath—that is, the line of junction of the two leaves—becomes brown with age while the thicker portion is still green.

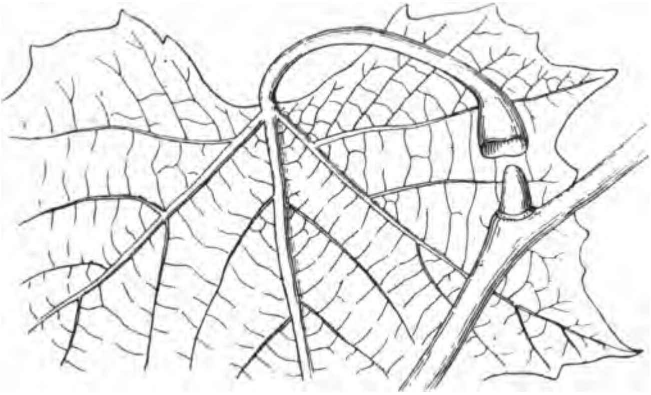


FIG. 7.—LEAF OF PLANE (*Platanus*), showing mode of protection of the young bud.

In other plants, as in *Stachys* (fig. 6), the leaves do not fit so closely, but the protection is enhanced by numerous hairs.

In the Plane (fig. 7) the base of the leaf-stalk is hollowed out, forming a sort of cup or extinguisher, which completely covers the young bud. By the time the leaf drops the outer envelopes of the bud are sufficiently developed and strengthened to protect the young and delicate leaves within.

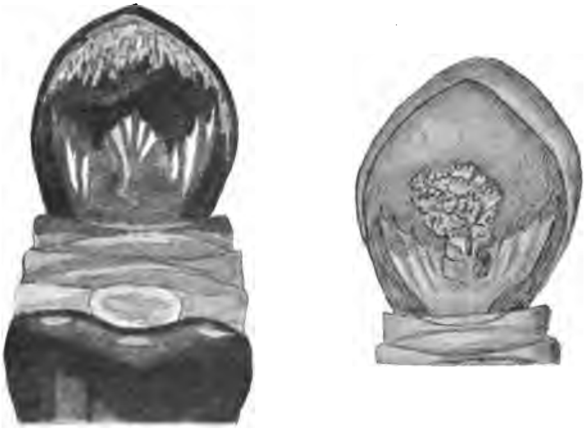


Fig. 8. **Fig. 9.**

Unopened Buds of Norway Maple. Enlarged.

Fig. 8 shows a leaf-bud. Fig. 9 is also a flower-bud.

In Monocotyledons it is a general rule that the bases of the leaves enclose and well protect the bud.

Though leaves and flowers come out with a surprising burst of vegetation in suitable spring weather, their development is slow and gradual. The summer buds, as I have already mentioned, contain the young leaves of the following year; the flowers of the Horse Chestnut or Maple (figs. 8 and 9) may be found in the bud in the preceding October; in some Conifers the development of the leaf even occupies two years, so that if we open a bud in the autumn we may find the rudiments not only of next year's leaves, but even of those of the spring following.

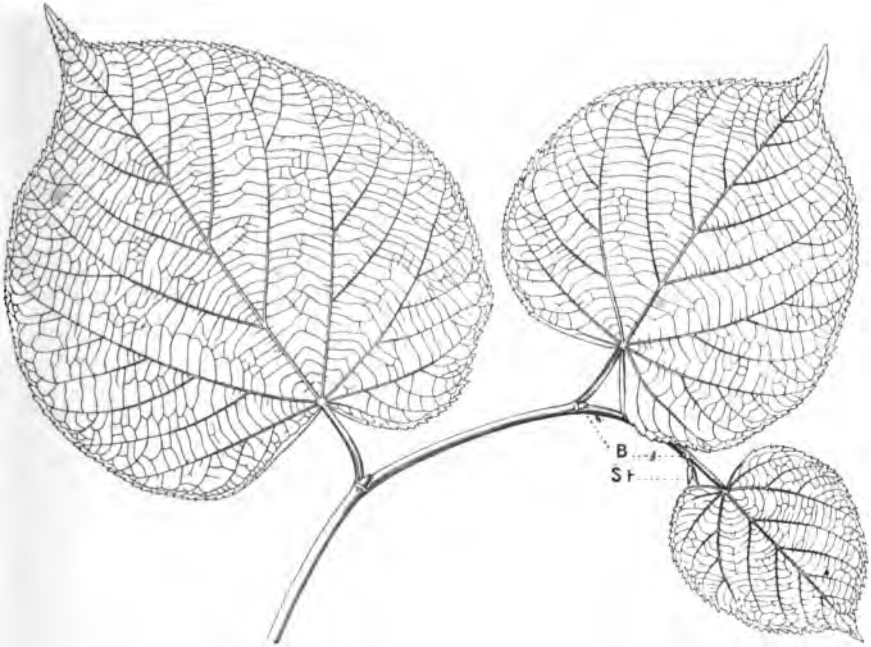


FIG. 10.—YOUNG SHOOT OF LIME (*Tilia*). Reduced.

St, stipules of terminal bud; B, axillary buds, the upper of which replaces the terminal bud on the fall of the latter.

There is a remarkable point about the Lime and some of our other forest trees and shrubs, which Vaucher (2) seems to have been the first to notice, namely, that the terminal buds die, and that very early. Fig. 10 represents a twig of Lime drawn at the end of May; the terminal shoot and stipules (*St*) are very small, and easily drop off. If a branch be examined a little later, it will be found to be terminated by a scar, left by the true terminal bud, which has dropped away, so that the one which is apparently terminal is really axillary.

Fig. 11 represents the end of a shoot of Hornbeam (*Carpinus Betulus*), taken in July, and shows how snugly the bud nestles between the stump of the terminal shoot and the petiole of the leaf.

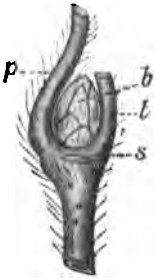


FIG. 11. — YOUNG SHOOT OF HORNBEAM (*Carpinus Betulus*), × 2.

p, base of petiole, the upper part having been cut off; *b*, bud; *t*, terminal shoot, the upper part has already dropped off; *s*, scar of stipule.

The same thing occurs in the Elm, Birch, Hazel-Nut, Lilac, Willow, &c. In these and many other species the bud situated apparently at the end of the branchlets is in reality axillary, as is shown by the presence of a terminal scar, due to the fall of the true terminal bud. I have found that even at the end of May the terminal buds of the Lime have almost all died and fallen away.

But why do the terminal buds wither away? In some cases the bud contains a definite number of leaves, but in the genera above mentioned the number is indefinite—more than can come to maturity; and yet the rudiments, which are constructed to produce true leaves, cannot modify themselves into bud-scales. Thus, in the Ash, Maple, Horse Chestnut, and Oak, which have true terminal buds, there are comparatively few leaves; while in the Elm there are about seven, Hornbeam eight, Lime eight, Willow fifteen, and Lilac fifteen.

In the above species it is generally the uppermost lateral bud or buds which develop, but in some cases, as in *Viburnum Opulus* (the Guelder Rose), *Gymnocladus*, &c., these also perish, and as a rule only the lower ones grow, and the upper part of the stem dies back.

The arrangement of the leaf in the bud influences, and sometimes determines, the form of the leaf.

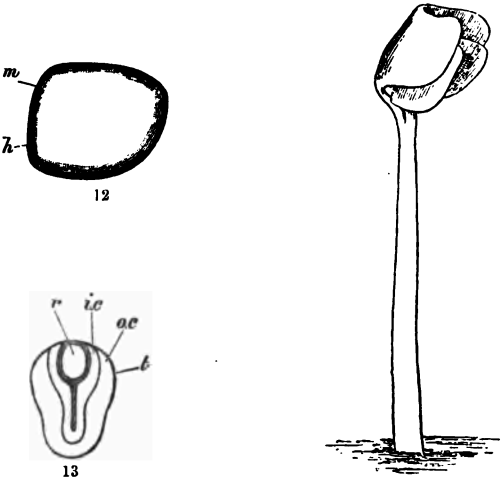
This consideration explains, I think, the curious fact that the first leaves, or cotyledons, often, indeed generally, differ altogether in shape from the true leaves. They offer an immense variety of form; not quite so innumerable, indeed, as those of true leaves, of which Linnæus truly observed[1] that 'Natura in nullâ parte magis fuit polymorpha quam in foliis,' but still immense. They may be large or small, broad or narrow, entire or much divided.

Now, why should the first leaves differ so much from their successors? The reason, I believe, is that while the forms of leaves often depend greatly on the buds, those of cotyledons are even more often influenced by the shape of the seeds. Let me give two instances in illustration.

---

[1] *Philosophia Botanica.*

I will take first the Common Radish (*Raphanus sativus*), with which, as regards the cotyledons, the Cabbage and Mustard closely agree. The seed of the Radish is shaped as in fig. 12. What regulates the shape of the seed is another question, into which I will not now enter. The young plant, consisting of two leaves, a small root, and a minute bud, occupies the whole interior of the seed. Each leaf is folded on itself like



FIGS. 12–14.—RADISH (*Raphanus sativus*).

12, outline of seed, × 4 : *m*, micropyle ; *h*, hilum ; 13, embryo in vertical section, × 4, showing the folded cotyledons and root (*r*) lying between them ; 14, germinating seedling, showing the cotyledons still folded, × 2.

a sheet of notepaper, and one lies inside the other. To this folding the emargination is due. If a piece of paper be taken, folded on itself, cut into the form shown in fig. 12, with the fold along the edge from *m* to *h*, and then unfolded, the reason for the form of the cotyledons becomes clear at once.

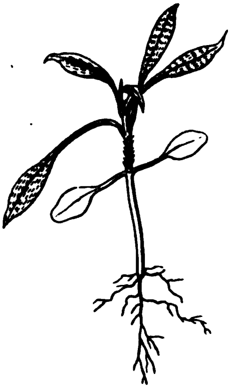


Fig. 15.—Seedling of Wallflower. Two thirds nat. size.

Now let us test this explanation by another case. The Wallflower has a seed of similar shape to that of the Radish, though thinner. Now, are the cotyledons of the same form as in the Mustard or Radish? Not at all. Those of the Mustard, as we have seen, are kidney-shaped; those of the Wallflower are racket-shaped, as in fig. 15. At first this seems a difficulty; but on looking closer the difficulty vanishes, for while the cotyledons of the Mustard are folded, this is not the case with those of the Wallflower, which lie flat in, and conform to the shape of, the seed, as shown in fig. 16. Thus the difference, which at first sight seemed a difficulty, is really a confirmation of the explanation suggested.

But we may even carry the matter a step farther. Why are the cotyledons of the Radish folded, and not those of the Wallflower? Because, as I have already mentioned, the seeds of the Wallflower are thinner than those of the Mustard, so that there would not be room for the four folds of the doubled leaves.[1]

In illustration of the influence which the form of the bud exercises on the shape of the leaf I may refer to my paper in the 'Contemporary Review' for May, 1885, to several memoirs in the 'Journal of the Linnean Society,' and to my book on 'Fruits, Flowers, and Leaves.' I will here only mention one or two cases. The leaves of the Tulip Tree (*Liriodendron tulipifera*) have long attracted attention from the peculiarity of their form. They are saddle-shaped, abruptly truncate at the end; or, in the words of Bentham and Hooker, 'sinuato-4-loba.' I long wondered what could be the purpose or the advantage to the tree of this remarkable

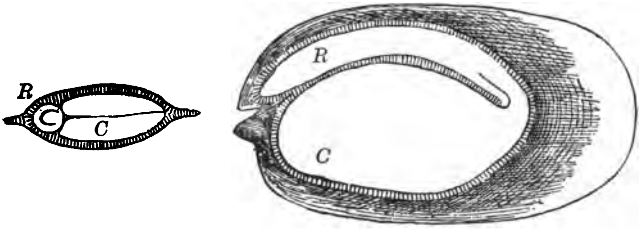


FIG. 16.—SECTIONS OF SEED OF WALLFLOWER. Transverse (left) × 10, and longitudinal (right) × 22.
R, radicle; *C*, cotyledon.

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[1] This interesting subject is dealt with more fully in my book on *Seedlings*.

shape. One idea which occurred to me was that the difference of form might enable insects to perceive the tree at some distance, just as the colours of flowers are an advantage in rendering them more conspicuous. I then looked closely to see whether the peculiar forms could in any way be explained by the position of the leaves on the tree. I believe, however, that the cause is of a different nature, and has reference to the peculiar character of the bud.

Each young leaf is, as in the family *Magnoliaceæ* generally, originally enclosed in and sheltered by the stipules of its predecessor. These are in *Liriodendron* oval, or in form resembling a shallow dish or spoon, so that when placed face to face they form a hollow almond-shaped box. Inside this lies the next younger pair of stipules; and the rest of the space is occupied by the young leaf, which is conduplicate, or folded on itself down the middle, like a sheet of notepaper, and also turned back towards the base of the bud. This unusual position is probably due to the early development of the petiole. The young stages in the development of the leaf are shown in figs. 17 and 18.

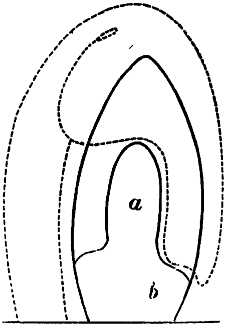

FIG. 17.—DIAGRAM SHOWING ARRANGEMENT OF THE YOUNG LEAF OF LIRIODENDRON.

Here it seems obvious that the peculiar form of the leaf is due to the form and arrangement of the bud.

M. Emery[1] has made some criticisms on my suggestions, which, however, I need not notice, for, having merely seen a short and incorrect abstract, and not having taken the trouble to refer to the original paper, he misunderstood my view, as M. Devaux pointed out at the time. I should gather also from his remarks that he can never have examined a bud in a very early state.

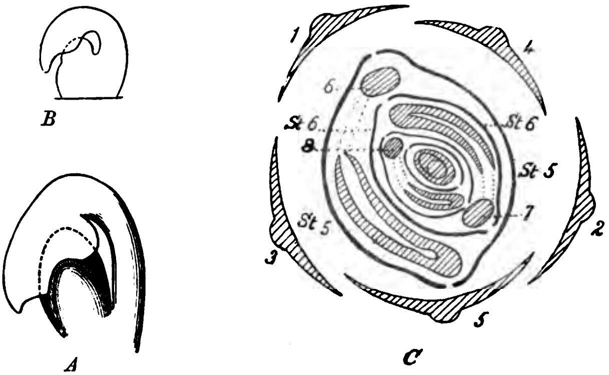

FIG. 18.—ARRANGEMENT OF YOUNG LEAVES OF LIRIODENDRON.

A corresponds with leaf No. 6 in *C*; *B*, next younger leaf; *C*, ground-plan of a bud, showing successive leaves (1-7), with stipules (*St* 5, &c.)

Or take, again, the case of the Oak and Beech. Both have a conical bud, and the young leaves are protected by stipules. I shall presently refer to them again from this point of view. For the moment I am dealing with the form of the leaf only. In both species the leaves, like those of *Liriodendron*, are conduplicate.

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[1] *Bull. Soc. Bot. France*, 1888, p. 327.

The leaves are in both species of about equal length, or those of the Oak are the longer; but the buds of the Beech (fig. 19) are much longer than those of the Oak (fig. 20). The young leaves of the Beech are able to lie straight in the bud; those of the Oak have not room to do so, and are, consequently, bent somewhat like a bow along the midrib. Now, if the outer edge

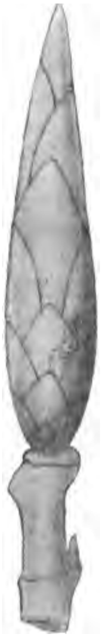

FIG. 19.—WINTER-BUD OF BEECH, × 2½.

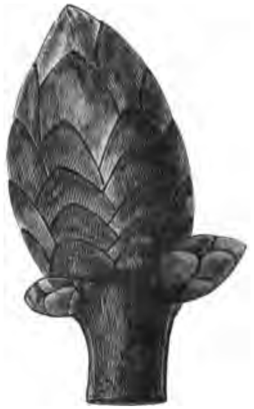

FIG. 20.—OAK BUD, × 6.

were straight, the result would be that when the young leaf emerged and straightened itself the edge must tear. This, however, is avoided by its being thrown into folds; and this, I believe, accounts for the lobes and bays so characteristic of the Oak leaf.

DORMANT AND ADVENTIVE BUDS

As a rule each leaf has a single bud in its axil; but there are two other classes of buds about which I must say a few words. In some species not merely one, but several buds arise in the axil. They appear to have been first noticed by Tristan (3). In such cases as, for instance, the *Robinia* ('Acacia') all but one of these, after attaining a certain stage of growth, become quiescent, and are gradually covered over by the bark. Such buds are known as 'dormant.' They may remain in the same state for years, but if the growing shoots are injured in the struggle for existence these reserves are called into the field. Their presence is often connected with that of thorns, as in *Robinia*, *Gleditschia*, *Colletia*, *Genista*, &c.; or with tendrils, as in *Passiflora*.

Another class of buds has been termed by Du Petit Thouars 'adventive' buds. They appear, especially in certain plants, on the leaves, internodes, and roots. They may be divided into two classes—natural and accidental.

Natural adventive buds are formed by *Cardamine pratensis*, *Dentaria bulbifera*, *Bryophyllum calycinum*, a considerable number of Dicotyledonous and Monocotyledonous plants, and many ferns.

A common example occurs in any abandoned field or waste ground bordered by Elm trees. The young plants which shoot up everywhere are not seedlings, but are formed by adventitious buds on the roots of the old trees; the considerable distance at which they appear from the parent emphasises the great length of the roots. Similarly, when a tree is cut down the ground becomes covered with a thick growth of young shoots, springing up rapidly, at the expense of the nourishment stored up in the roots which remain in the ground. Such shoots are also common in Poplars, Limes, many fruit trees, &c.

Accidental adventive buds are those which appear if the plant is maimed or wounded; or if a leaf, say of Begonia, is detached from the parent plant and placed on damp earth.

Goebel, in his recently published 'Organographie,' figures an interesting case of the growth of a new plant at the end of the stalk of a detached leaf. The plant in question is a garden hybrid belonging to the same family as *Gloxinia* (fig. 21). The leaf was taken from a plant which was just about to flower, and the adventitious shoot has straightway produced flowers.

To eradicate Docks from a garden the whole plant must be removed, as adventitious buds will arise on any broken piece of root which is left behind The same applies to Dandelions or Plantains. The natural adventive buds appear on definite parts of the plant, according to the species; in accidental adventive buds the place of origin depends on that of the injury.

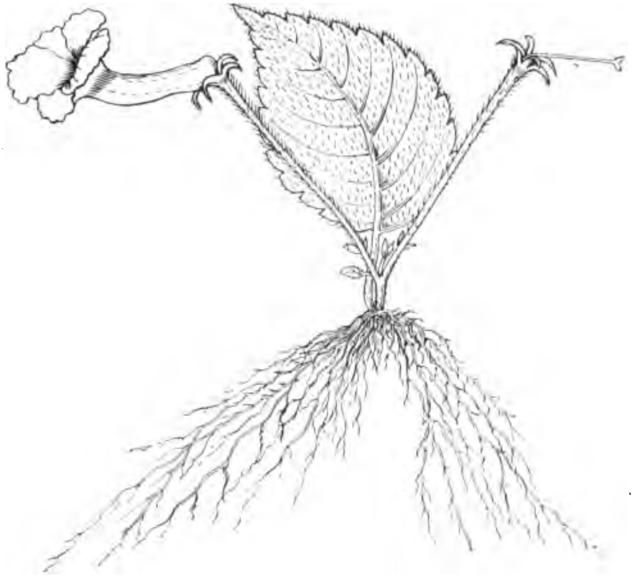

FIG. 21.—ACHIMENES HAAGEANA, showing development of a new flowering plant consisting of root and flowering-shoot.

Adventitive shoots may arise, like normal shoots, exogenously; but endogenous development generally occurs when they arise from older parts of stems or roots. In some cases they are formed by the direct conversion of the growing-point of a root, as in Bird's Nest Orchid (*Neottia Nidus-Avis*), *Catasetum tridentatum*, &c.

CHAPTER II

ON STIPULES

VAUCHER, in his 'Histoire Physiologique des Plantes,' writing on the Rock Roses (*Helianthemum*), observes:

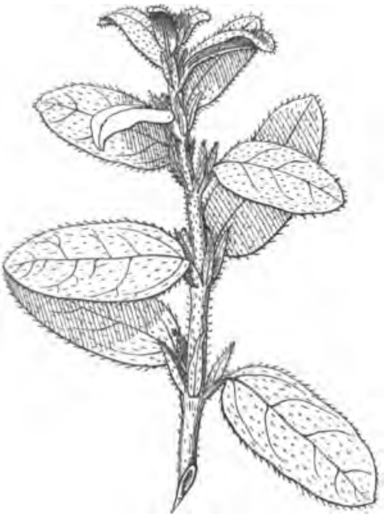

FIG. 22.—SHOOT OF HELIANTHEMUM VULGARE. Slightly enlarged.

'J'indique dans ce genre deux principaux objets de recherche. Le premier est la raison pour laquelle certaines espèces ont des stipules tandis que d'autres

en sont privées.' This suggestion started me on the present inquiry. No one, so far as I know, had attempted to answer Vaucher's question, which is one of considerable interest, and might be asked with reference to several other groups besides the genus *Helianthemum*. The results of my observations have been embodied in several Memoirs which the Linnean Society has done me the honour to publish in their 'Journal,' and I now propose to bring together those portions which seem to be of general interest.

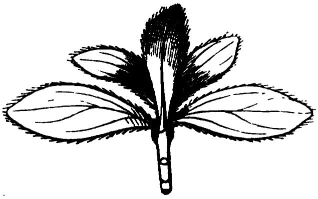

FIG. 23.—SHOOT OF HELIANTHEMUM ŒLANDICUM. Slightly enlarged.

Fig. 22 represents a shoot of *Helianthemum vulgare* (the Common Rock Rose), with stipules; Fig. 23, one of *Helianthemum œlandicum*, which has none.

Malpighi, in his 'Anatomy of Plants' (1671), seems to have been the first who mentions these organs, which he terms (p. 29) 'folia caduca,' in opposition to the ordinary and generally, though by no means always, more permanent leaf-blades. Almost at the same time (1672) they were noticed and described by our countryman Grew, who called them interfoils.[1] Linnæus gave them the name of stipules ; from *stipula*, a little straw. This term happily expresses their appearance in such a case as that of the Beech, but they present great differences in size, form, and texture.

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[1] *The Anatomy of Plants*, p. 146.

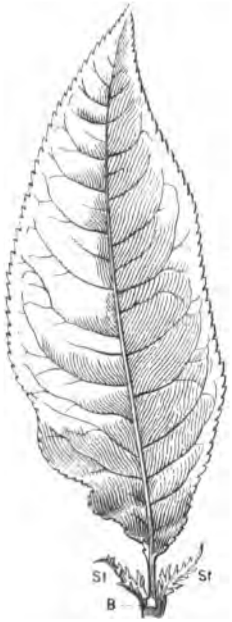

FIG. 24.—LEAF OF PEACH. Two-thirds nat. size.
St, stipules ; B, axillary bud.

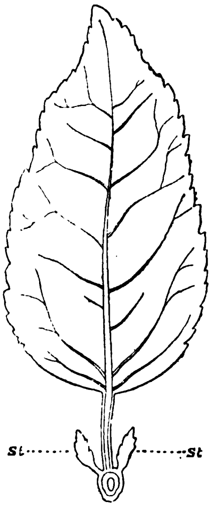

FIG. 25.—LEAF OF PORTUGAL LAUREL. One-third nat. size.
St, *St*, stipules.

The Peach (fig. 24) and Portugal Laurel (fig. 25) are good examples of a typical simple leaf with a pair of stipules at the base of the stalk.

Stipules present, however, a great variety of forms. Those, for instance, of the Common Garden Pea (*Pisum sativum*) (fig. 26) are large, oblong-oval, mucronate, unequal-sided, and unequally toothed at one side. They cover the rest of their own leaf in the young stage and all the rest of the bud.

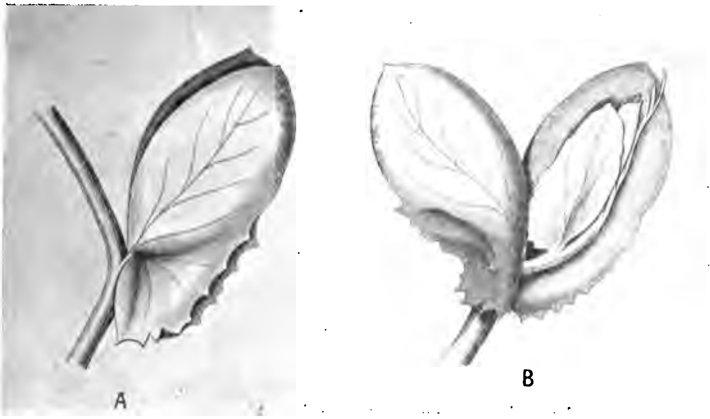

FIG. 26.—STIPULES OF PEA BEFORE THE UNFOLDING OF THE LEAF. A, natural position; B, one stipule turned back, showing the rest of the leaf.

In the Pansy (fig. 27) they are large, oblong, and pinnatifid, with 3–6 linear lobes on the external side.

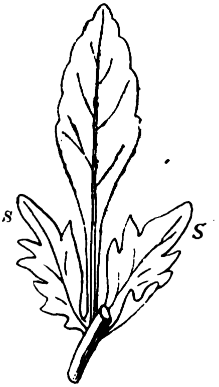

FIG. 27.—LEAF OF PANSY Three-fourths nat. size. *S*, *S*, stipules.

In *Hymenanthera* (fig. 28), a

shrub also belonging to the family of the Violets, the stipules are small.

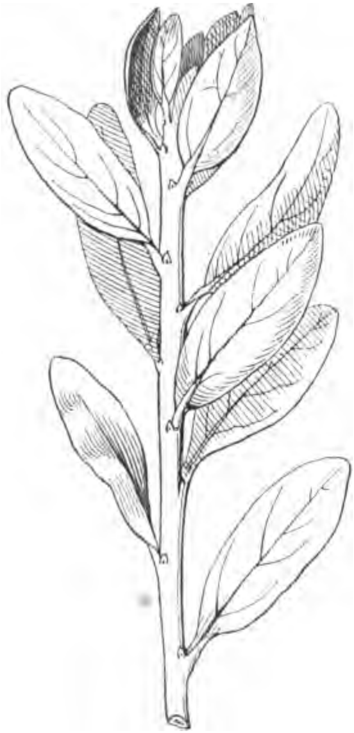

Fig. 28.—Shoot of Hymenanthera crassifolia, × 2.

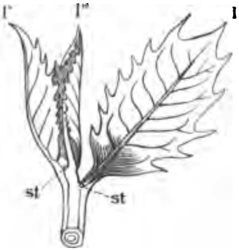

Fig. 29.—Young Shoot of Holly. Nat. size.
l', *l''*, *l'''*, successive leaves;
st, *st*, stipules.

In other cases stipules are even more minute, as in the Holly (*Ilex Aquifolium*) (fig. 29). Here they are perhaps functionless; the mere rudiments of once larger organs.

In other cases, however, as for instance in *Guaiacum officinale* (fig. 30), though the stipules are small, still they afford a very efficient protection to the minute bud.

For other illustrations of bud-protection by stipules, see Plate I. figs. 1 and 2, the Lime; figs. 4 and 5, the Hornbeam; Plate III., the Wych Elm; and Plate IV., the Beech.

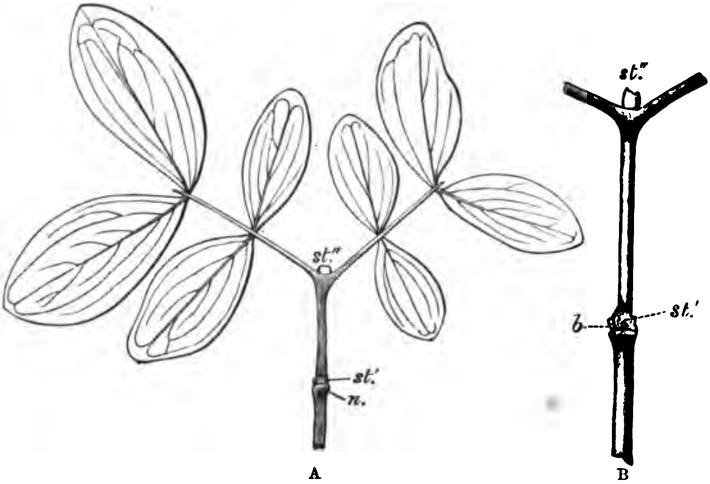

Fig. 30.—Guaiacum officinale.

A. Terminal shoot, nat. size: *n*, node; *st'*, connate stipules; *st''*, connate stipules covering the terminal bud.

B. Terminal shoot with lamina of leaves removed, ×2; *st'*, *st''*, stipules as in A; *b*, lateral bud.

Stipules are sometimes situated on the leaf-base, sometimes at the foot of the leaf-base, sometimes on the stem just below the leaf-base.

In the Dwarf Elder (*Sambucus Ebulus*) they are comparatively large; while in the Common Elder (*Sambucus nigra*, fig. 31) they are minute or altogether absent.

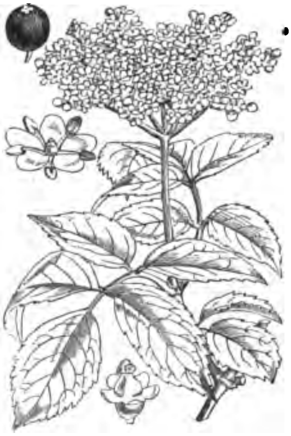

Fig. 31.—Young Shoot of Elder (*Sambucus nigra*).

In many cases the stipules differ in shape and size, even in the same plant. Of this the Common Thorn (*Cratægus Oxyacantha*) (fig. 32) affords a good illustration.

As regards their colour, leafy stipules are generally green; the minute stipules of the Holly (*Ilex Aquifolium*) are black; the scales of buds are various shades of brown, shading off to white; scarious stipules range from straw-colour to grey. Some are beautifully coloured, almost like the petals of flowers: in the Hornbeam, for instance, often of a bluish purple (Pl. I. figs. 4 and 5); and in the Wych Elm (Pl. III.) a red purple; in the Lime a rich crimson, or even bright ruby (Pl. I. figs. 1–3).

Stipules, when large and foliaceous, resemble in texture the leaves of which they form a part. The outer stipular scales of many buds are tough and leathery, the inner ones more membranous, and often very delicate, thin, and almost transparent. Others develop into hard, woody spines, as in *Robinia* (so-called Acacia), &c. (figs. 33, 34).

As regards the duration of life, some stipules, such as those of the Beech, Oak, Elm, &c., which only serve to protect the young leaves, drop off as soon as the latter expand. The ground under Beeches in spring is almost brown with fallen stipules.

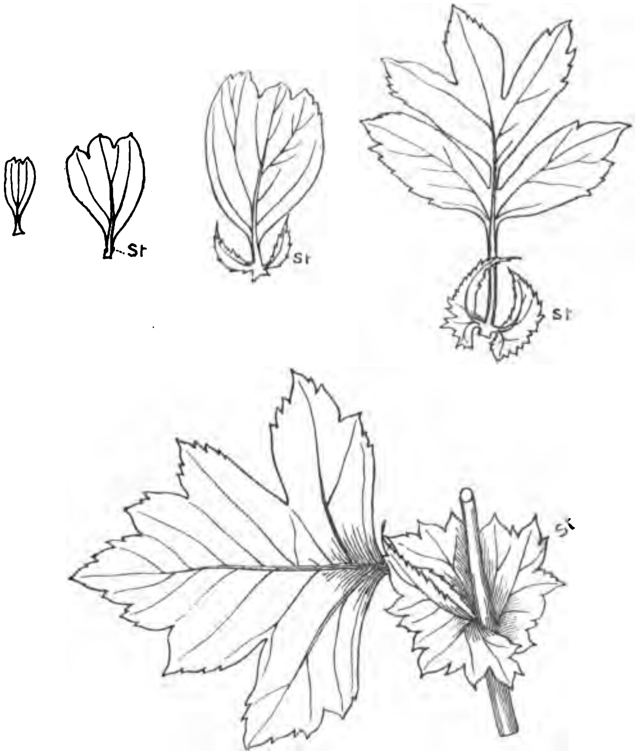

Fig. 32.—Five Leaves of the Common Thorn. Nat. size.
St, stipules, absent in the first figure.

Others, as, for instance, those of the Pea, Pansy, Bedstraw, &c., which assist in performing the ordinary function of leaves, live as long as, and drop with, the leaves to which they belong.

Lastly, there are some, though they are exceptional, which survive the rest of the leaf and protect the next succeeding bud, as, for instance, in *Petteria* (figs. 35, 36); or they may last indefinitely, as in *Robinia.*

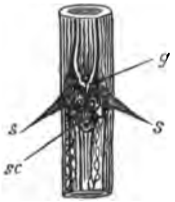

FIG. 33.—ROBINIA VISCOSA. Nat. size.

s, *s*, spiny stipules sketched in winter (Jan. 25, 1897); *sc*, scar of fallen leaf; *g*, gland above the bud.

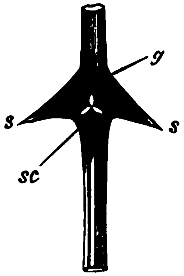

FIG. 34.—ROBINIA PSEUDACACIA, VAR. DECAISNEANA. Nat. size.

s, *s*, spiny stipules sketched in winter (March 13, 1897); *sc*, scar of fallen leaf; *g*, gland above the bud.

In certain cases most of the stipules of a species are caducous, while some of them are persistent.

Thus, in the Black Poplar (*Populus nigra*), (fig. 37) the stipules of the upper leaf often survive the leaf-blade, which drops off in autumn, while they retain their place and protect the young bud through the winter.

When stipules survive the rest of the leaf to which they belong, this generally has reference to the protection of the buds. Thus, in *Magnolia Umbrella* the leaf terminating each year's growth is small, and eventually the blade becomes disarticulated just above the stipules, which are adnate to the leaf-base and enclose the bud (fig. 38). These stipules are in this species the only ones which survive the leaf-blade.

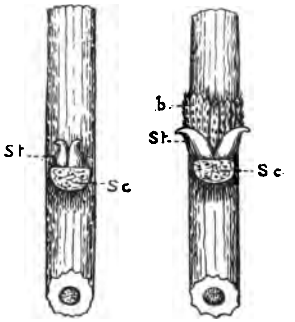

FIG. 35. FIG. 36.

PETTERIA RAMENTACEA.

FIG. 35.—Portion of shoot in winter, × 2.
FIG. 36.—Ditto in spring, × 2. *Sc*, scar of fallen leaf; *St*, stipules completely covering the bud in fig. 35, in fig. 36 pushed aside by the developing bud (*b*).

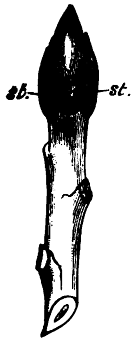

FIG. 37.—POPULUS NIGRA. TERMINAL WINTER-BUD, showing a pair of persistent stipules (*st*) belonging to a leaf of last season, × 2.

Some other species of Magnolia—for instance, a garden hybrid, *M. Soulangiana*—agree with *M. Umbrella* in these respects.

In some cases, however, as in the so-called Acacia (*Robinia*), the thorny stipules assist in the protection of the plant as a whole.

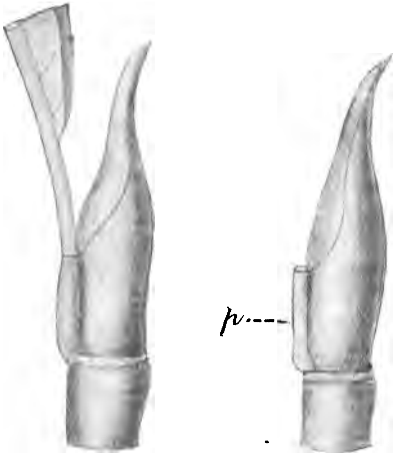

Fig. 38.—Magnolia Umbrella, showing disarticulation of the leaf-stalk above the stipules, which are wrapped round the terminal bud. Before and after the fall of the leaf.

p, pedestal or persistent base of petiole.

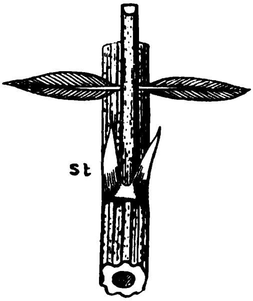

Fig. 39.

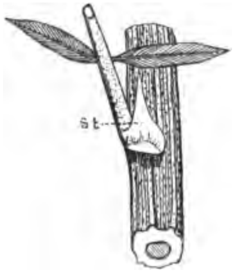

Fig. 40.

Portion of Shoot of Astragalus chinensis, showing stipules (*St*) connate at the base. Nat. size.

Fig. 39.—Front view. Fig. 40.—Side view. Two leaflets of the compound leaf are shown.

Where stipules are present the leaf has two, one on each side. Sometimes, however, the two stipules are connate, *i.e.*, have grown together. This may take place on the outside of the leaf, and be either confined to the base, as in a Chinese Astragalus (*Astragalus chinensis*), (figs. 39, 40), or continue for the greater part of their length, as in *Hedysarum esculentum* (figs. 41, 42), where they are reddish brown and membranous, and develop early, so that the leaves at this stage lie between two rows of stipules. In Sainfoin (*Onobrychis sativa*) (figs. 43, 44) also the stipules are united for the greater part of their length. In other species they are 'intrapetiolar,' more or less connate on the axillary side of the leaf, as in the Pondweed (*Potamogeton*) (fig. 45) and in the Knotweeds (*Polygonum*) (fig. 46), where they form the sheath, called technically an ocrea.

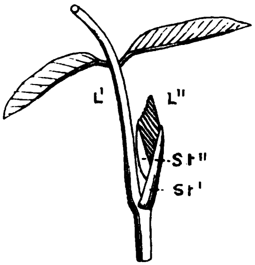

FIG. 41.

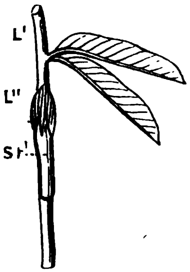

FIG. 42

HEDYSARUM ESCULENTUM. Nat. size.

FIG. 41.—Apex of growing shoot, showing side view of stipules; L', youngest, partly expanded leaf, with the lowest pair of leaflets still folded, and the stipules, *st'*, connate opposite the leaf-base; L'', next younger leaf pushing out of the bud with its stipules, *st''*.

FIG. 42.—The same showing the dorsal aspect of the connate stipules, *st'*.

The Hop also has connate stipules, but in this case the two which have coalesced belong to two opposite leaves (figs. 47, 48). Such stipules are termed 'interpetiolar.'

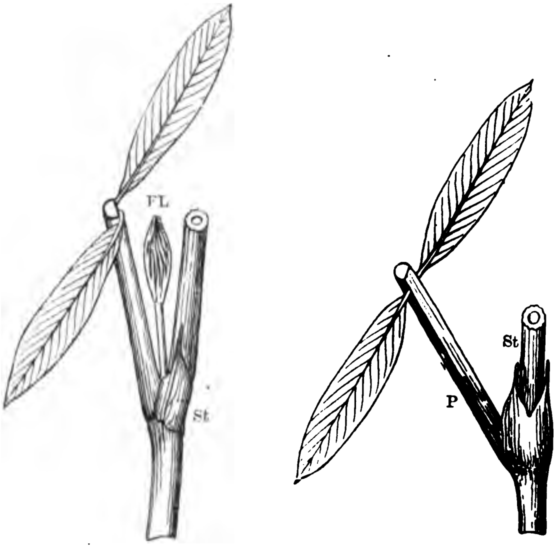

FIG. 43. FIG. 44.

ONOBRYCHIS SATIVA, showing stipules (*St*) united for the greater part of their length.

FIG. 43.—Side view. FIG. 44.—Back view. *P*, leaf-stalk; *FL*, a flower-bud.

In *Spergularia* (fig. 135, p. 88) the stipules are free from the leaves, but connate at the base, forming a sheath, which envelops the base of the leaves.

De Candolle observes that the existence of stipules 'paraît liée assez intimément avec la symétrie générale des plantes, car elles existent ou manquent dans toutes les espèces d'une famille : ainsi, on trouve des stipules dans les Rubiacées, les Malvacées, les Amentacées, les Légumineuses, les Rosacées, etc., et elles manquent dans toutes les Caryophyllées, les Myrtacées, &c.'

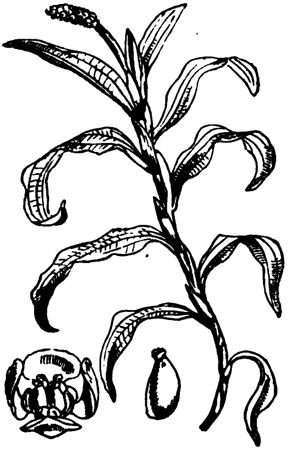

Fig. 45.—Potamogeton lucens, showing intrapetiolar stipules.

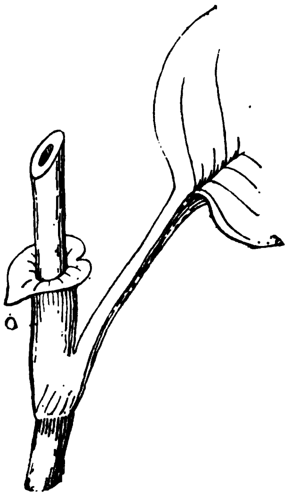

Fig. 46.—Polygonum, showing Ocrea (o).

This, however, is not so general a truth as De Candolle imagined. The absence of stipules is not complete in either of the families mentioned by him. They occur not only in *Spergula* and *Spergularia*, which are now generally considered as belonging to the *Caryophyllaceæ* (though certain botanists regard them as constituting a separate family), but also in most of the *Polycarpeæ*; and among the *Myrtaceæ* in *Calythrix*, *Couroupita*, and perhaps in some other genera.

Among other families some genera of which have stipules, while others are exstipulate, may be mentioned the *Onagrarieæ*, *Saxifrageæ*, *Geraniaceæ*, *Leguminosæ*, *Sapindaceæ*, and *Euphorbiaceæ*. Moreover, as pointed out in the above passage from Vaucher, there are even certain genera—and in addition to *Helianthemum* I

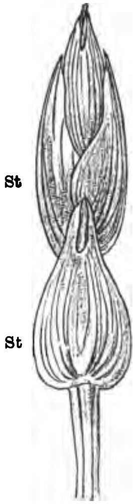

FIG. 47.—END OF SHOOT OF HOP, × 3, showing connate stipules (*St*).

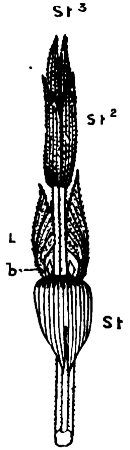

FIG. 48.—END OF SHOOT OF HOP. Nat. size.

St, connate stipules folded back to show the pair of leaves (L) to which they belong; *b*, axillary buds; St^2, next higher pair of stipules, overlapping by their edges along the median line of the axis, and with the next higher pair (St^3) covering the terminal bud.

might mention *Lathyrus*, *Genista*, *Passiflora*, *Acacia*, *Spiræa*, *Saxifraga*, *Rosa*, *Berberis*, &c.—in which some species have stipules while others have none.

While, then, in most families of plants the species are all either stipulate or exstipulate, there are a good many families in which the genera differ in this respect; some genera in which the species differ; and, lastly, there are some cases, even within the limits of a single species, in which certain leaves are said to develop stipules, and others to be exstipulate, as for instance *Helianthemum guttatum*, *Ipomœa pendula*,[1] *Exochorda Alberti*, &c.

Let us now return to Vaucher's problem—Why should some species of *Helianthemum* have stipules, and others not?—and see whether we can find the answer to it.

Our common *Helianthemum* (*H. vulgare*) has stipules; so have *H. polifolium*, *H. tomentosum*, *H. ægyptiacum*, *H. rhodanthum*, *H. ciliare*, *H. lavandulæfolium*, and *H. rosmarinifolium*. On the other hand, there are a number of species which have no stipules: *H. œlandicum*, *H. lasianthum*, *H. ocymoides*, *H. formosum*, *H. Libanotis*, and others. Now, in *H. œlandicum* (fig. 23) the plant is dwarf and prostrate; the leaves are opposite, oblanceolate or spathulate, tapering to a broad base, sessile, ciliate, especially at the base, which also widens so as closely to sheathe the young bud, thus effectually protecting it. So, also, in the other exstipulate species the leaf-stalks are all more or less widened at the base, and the bud is thus protected.

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[1] Choisy, in De Candolle's *Prodromus*, ix. p. 387.

On the other hand, our common *Helianthemum* (*H. vulgare*) (fig. 22) has the leaf-stalk narrowed at the base, and glabrous or nearly so. The bud, therefore, would be exposed if it were not for the stipules. So, also, in the other species which have stipules the leaf-stalks are narrowed at the base, and the buds are protected by the stipules.

Hence we have a very strong presumption that the answer to Vaucher's problem is that some species of *Helianthemum* have stipules in order to protect the buds; and that in others, where this function is performed by the dilated bases of the leaf-stalk, stipules would be unnecessary, and do not occur.

Helianthemum guttatum is particularly interesting in this respect. The upper leaves have stipules, while the lower ones have none. Now the lower leaves have broad leaf-bases, which effectually protect the bud, and they are exstipulate; the upper leaves, on the contrary, are narrow at the base, but they are provided with stipules.

The reason for the presence or absence of stipules seems, then, quite obvious, so far as the Rock Roses (*Helianthemum*) are concerned.

Let us now see whether the conformation of other species supports this view. In the allied genus *Cistus*, which has no stipules, the petiole is always widened as in the species of *Helianthemum* without stipules.

This is shown, for instance, in the following figure of *Cistus cyprius* (fig. 49).

In *Cistus vaginatus* (fig. 50) the petioles are connate for some distance, so as to form a sheath.

It may, however, be objected that this is hardly a case in point, because none of the species of *Cistus* have stipules, and the petioles are all widened at the base.

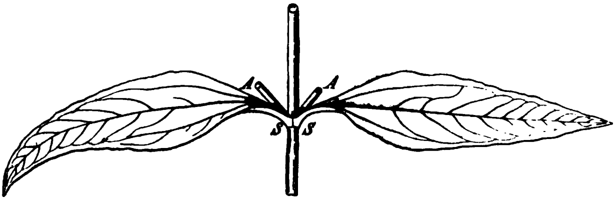


FIG. 49.—SHOOT OF CISTUS CYPRIUS. Reduced one-half. *S*, *S*, connate sheaths of leaves; *A*, *A*, axillary shoots.

There are, however, as already mentioned, some other families of plants in which some species have stipules and others have not.

For instance, in the *Caryophyllaceæ* (the Pink family), the genera *Spergula* and *Spergularia* have stipules, while the others are exstipulate. Now *Spergula* and *Spergularia* have narrow petioles, while in the other genera—*Dianthus*, *Tunica*, *Gypsophila*, *Saponaria*, *Silene*, *Lychnis*, *Cerastium*, *Arenaria*, *Sagina*, &c.—containing a very large number of species, the basal part of the leaves is always more or less connate and sheathing, or the petioles are widened so as to protect the bud.

Again, the *Guttiferæ* have broad petioles and no stipules. *Quiina*, however, is an exception, for it has stipules, and here also the petiole is narrowed at the base.

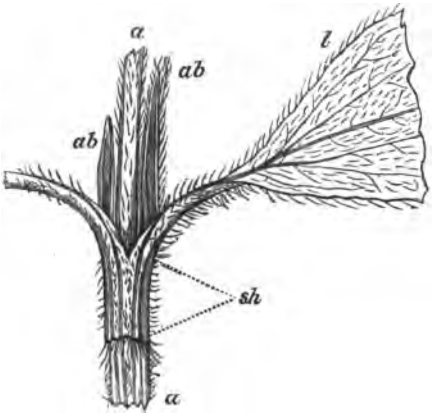
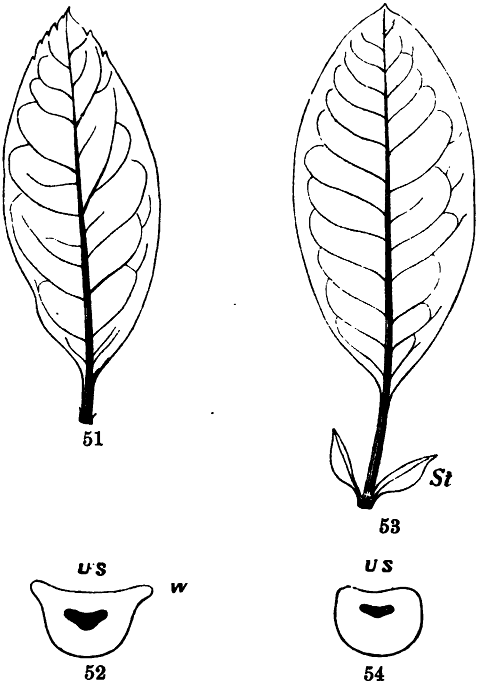


FIG. 50.—CISTUS VAGINATUS. Nat. size.
a a, axis ; *l*, portion of leaf ; *sh*, sheath formed by the dilated and connate bases of the petioles ; *ab*, *ab*, axillary buds.

The *Rosaceæ* generally have stipules, but in *Exochorda* some species are exstipulate. In *Exochorda Alberti* (figs. 53, 54), for instance, the leaves have well-developed foliaceous stipules.

On the other hand, *Exochorda grandiflora* (figs. 51, 52) is exstipulate. The petiole, however, is concave and amplexicaul, and the winter-bud is covered with a number of broadly triangular brown scales, some of which show indications of being tridentate at the apex. These lateral teeth are probably evidence of the former existence of stipules. The petiole of the lower leaves also sometimes shows short teeth at its upper end, which also probably represent the last trace of stipules.



LEAVES OF EXOCHORDA.

FIG. 51.—Leaf of *Exochorda grandiflora*, nat. size.
FIG. 52.—Transverse section of petiole at 3 mm. from base, ×12; *US*, upper surface; *W*, wing.
FIG. 53.—Leaf of *Exochorda Alberti*, nat. size; *St*, stipule.
FIG. 54.—Transverse section of petiole at 3 mm. from base, ×12; *US*, upper surface.

Among the *Magnoliaceæ*, some genera have stipules, while in others they are entirely absent. In *Drimys Winteri*, for instance, they are replaced by some of the outer leaves of the resting bud, which are reduced to bract-like fleshy scales. The leaves are convolute, the lower enclosing the upper ones.

Again, in *Kadsura* (*K. japonica*) the winter-buds are protected by the outer leaves, which are reduced to scales, and appear to consist of flattened petioles, with a membranous margin representing stipules, free only at the tip. The true leaves follow the scales abruptly.

Another very interesting case is that of *Viburnum.*[1]

We have in this country two wild species of this genus—one, *Viburnum Lantana* (usually known as the Wayfaring Tree) (fig. 55); the other, *Viburnum Opulus* (fig. 56). They are not rare in woods, especially in chalky districts; but, though very nearly allied, their leaves are remarkably different. I extract the following descriptions from Syme.[2]

Of *V. Opulus* he says: 'Leaves deciduous, stalked, roundish in outline, three-lobed, with the lobes acuminate, coarsely toothed and ciliated, finely pubescent, but not furfuraceous beneath. Petioles with adnate stipuliform appendages in the form of one (or sometimes two) linear process on each side, a little above the base.' There are, I may add, two or more honey-glands at the base of the lamina of the leaf.

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[1] This is taken from a paper read by me before the Linnean Society on February 20, 1890 (*Journ. Linn. Soc.* xxviii. p. 244).

[2] In Sowerby's *English Botany*, 3rd ed. iv. pp. 202 and 203.

Of *V. Lantana* he says: 'Leaves very shortly stalked, without stipules, ovate-oval or elliptical-oval, dentate-serrulate, deciduous, rugose, furfuraceous-pubescent beneath, especially on the veins, at length nearly glabrous.' There are no honey-glands.

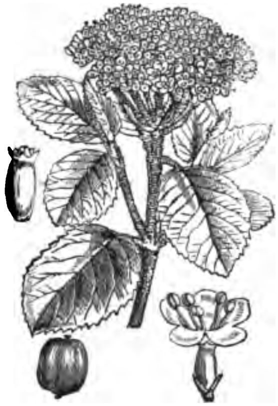


FIG. 55.—VIBURNUM LANTANA.

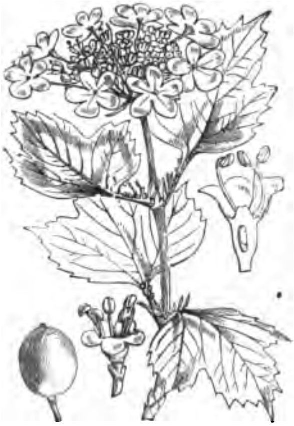


FIG. 56.—VIBURNUM OPULUS.

No attempt, so far as I know, has been made to account for the difference in form of the leaf in species so nearly allied; for the presence of the honey-glands in the one and not in the other; nor to explain the reason for the existence of the peculiar filiform stipuliform appendages, nothing exactly resembling which occurs in any of our other forest trees, the nearest approach being in the allied genus *Sambucus.* The presence of stipules in *Viburnum* would be the more remarkable, as in the family *Caprifoliaceæ*, to which the *Viburnums* belong, stipules (if they be stipules) are confined to this genus, to *Pentapyxis*, and to *Sambucus.*

According to De Candolle's 'Prodromus,' there are forty-one species of *Viburnum*; and though some more must now be added, this would not materially affect the question. Of these forty-one, thirty-five have the leaves entire, and more or less resembling those of *V. Lantana.* None of these possess stipules. The other six have lobed leaves, more or less like those of *V. Opulus*, and these all have stipuliform appendages, the existence of which would seem, therefore, to be connected with the presence of the lobes.

The existence of honey-glands at the base of the leaf is also, perhaps, connected with the texture of the leaf.

In *V. Lantana* the covering of felted hairs affords a sufficient protection; but the tender young leaves of *V. Opulus* would afford a tempting food to many caterpillars and other insects. The ants and wasps which are attracted by the honey would tend to keep them down, and thus to serve as a bodyguard. Indeed, it has appeared to me that on specimens of *V. Opulus*, which are much frequented by wasps and ants, the leaves are less eaten than in other cases where they are not so protected.

I now come to the stipuliform appendages. These often bear honey-glands, but by no means always, and even where these occur there seems no reason why they should be situated on filiform appendages. On the whole, then, I doubt whether they can be explained as mere honey-glands, or whether, indeed, they are of any actual use when the leaves are fully developed.

When we meet with a small organ which appears to have no definite function, we naturally ask ourselves whether it is the disappearing relic of some larger organ which at one time performed some useful purpose in the economy of the animal or plant. This suggestion, however, seems untenable in the present case, because, as a matter of fact, we do not find that the stipuliform appendages are more developed in any of the species allied to *V. Opulus*.

There is, however, a physical cause to which, perhaps, the presence of these organs may be due. We have seen that much the larger number of species of *Viburnum* have entire leaves, more or less oval or ovate. This would appear to be the form typical or original to the genus.

Now let us suppose that, either from having extended northwards (and both *Viburnum Lantana* and *V. Opulus* are among the northern representatives of the genus), or from some other cause, the young leaves require additional protection. This may be effected in several ways. For instance, the young leaf may be guarded by a thick coat of felted hairs; this is the case in *V. Lantana.* Another plan would be that the outer leaves should become leathery, and thus protect the inner ones; this is the case with *V. Opulus.* But that being so, it is an advantage that the inner or true leaves should be folded, because they thus occupy less space. This, perhaps, accounts for the folding of the leaves of *V. Opulus* in the bud, while the lobes follow from the mode in which the leaves are folded. Now a leaf folded up, as are those of *V. Opulus*, requires only two or three lateral veins. The remaining veins, then, and the membrane connecting them, will gradually be reduced, and ultimately disappear.

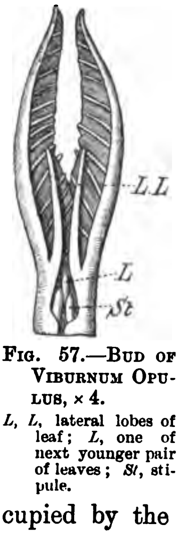


FIG. 57.—BUD OF VIBURNUM OPULUS, × 4.
L, *L*, lateral lobes of leaf; *L*, one of next younger pair of leaves; *St*, stipule.

In *V. Opulus*, as is shown in the figure (fig. 57), there is a space left between the bases of the leaves. In the genus *Acer*, many species of which have leaves somewhat resembling those of *V. Opulus*, this space is fully occupied by the following pair of leaves. This, however is not the case in *V. Opulus*, and the space thus left unoccupied is filled up by the stipuliform appendages. I may also observe that the stipuliform appendages resemble leaf-lobes in being slightly conduplicate.

These considerations seem to throw some light on the differences between the leaves of *Viburnum Lantana* and *V. Opulus*—the hairiness of the former and the smoothness of the latter; on the lobed form of the leaf in the latter; and, lastly, on the presence of the honey-glands and the peculiar stipuliform appendages in *V. Opulus*, neither of which occur in *V. Lantana.*

In support of the above suggestions I may refer to the interesting analogy afforded—in a totally different family—by the genus *Spiræa.* Here we find some species with entire, some with pinnate leaves; while those of *S. opulifolia,* as the name denotes, closely resemble those of *Viburnum Opulus.* Now the entire-leaved species of *Spiræa,* like those of *Viburnum,* have no stipules; while *Spiræa opulifolia* agrees with *Viburnum Opulus* not only in the shape of the leaves, but in the mode of folding in the bud, and also in the presence of subulate, acuminate, stipuliform appendages.

I might give other cases, but the above will, I think, be sufficient. It seems clear that the answer which we had provisionally arrived at from a study of the Rock Roses is fully borne out by the examination of other families, and that when the bud needs protection and the petiole is narrowed, this function is performed by the stipules; while, when there are no stipules, the bud is protected in some other way, and generally by the widened base of the leaf-stalk.

But though the protection of the bud is the general, it is, as we shall presently see, by no means the only function which stipules perform in the economy of plants.

CHAPTER III

ON THE DEVELOPMENT OF LEAVES AND STIPULES

IN order to arrive at a satisfactory view as to the structure and arrangement of buds it is necessary to study the development of the leaf. Steinheil (4), in 1837, was the first who approached the consideration of the subject in this rational manner; and we are also indebted for excellent memoirs and observations to De Mercklin (5) in 1846, Trecul (6) in 1853, Schacht (7) in 1854, Eichler (8) in 1861, Goebel (9), and others.

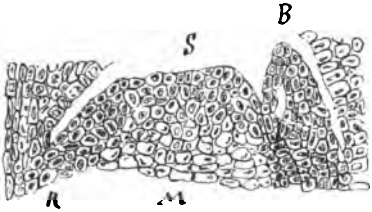


FIG. 58.—GROWING-POINT AND BEGINNING OF FIRST LEAF OF ROSE. Highly magnified.

S, apex of growing-point; *B*, youngest leaf; *R*, cortex; *M*, pith.

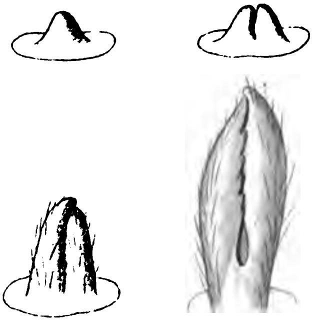
Speaking generally, we may say that a leaf commences as a small conical projection immediately below the growing-point of the shoot (fig. 58). It continues to grow at its apex for a short time only, its development being completed by growth in a zone of cells situated just above its base (intercalary growth). So that, as Schleiden has pointed out, while the apex is the youngest part of the shoot, it is the older part of the leaf. The projection gradually widens, and often occupies more than half the circumference, thus affording a possible explanation of the fact that, while the cotyledons are opposite, the leaves are in so many cases alternate.

The rudimentary leaf consists of undifferentiated cellular tissue, and does not at first contain any vessels.

It is no part of my present intention to deal with this interesting subject in detail, but I will give a few cases in illustration, taking that of ordinary foliage leaves, for in those which are intended as bud-protectors the stages are very different.

AUCUBA

On account of its simplicity, I will commence with the common *Aucuba japonica* of our shrubberies. The leaves of *Aucuba* are opposite, ovate, and without stipules. They commence as two slight projections, each of which broadens at the base, and finally occupies one-half of the circumference of the stem (figs. 59, 60), so that they are concave on the inner side and almost cover over the growing-point. They gradually elongate (fig. 61), and from being at first slightly curved round the stem, become folded lengthways or conduplicate. They are clothed with long, sparse hairs, and show a few teeth, or rather knobs, along the edge, one terminating each of the veins, which are thicker than in subsequent stages (fig. 63). The teeth, or knobs, are also much larger in proportion than in the full-grown leaf.



Figs. 59–62.

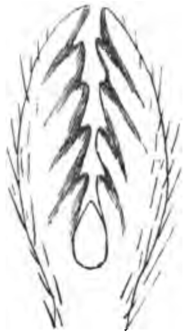


Fig. 63.

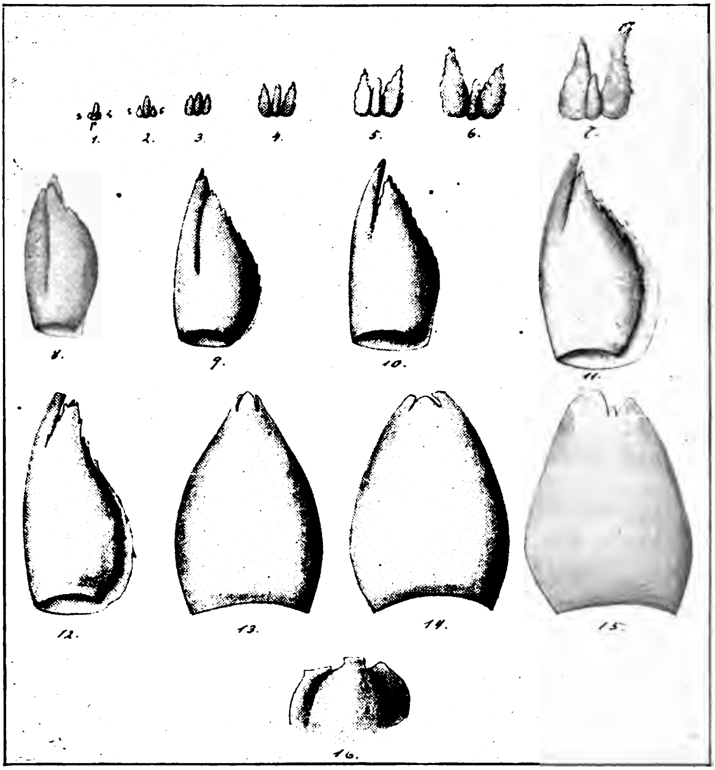
Aucuba japonica. Highly magnified.

Fig. 59, first pair of leaves, front view; Fig. 60, ditto, side view; Fig. 61, second pair; Fig. 62, ditto, more developed; Fig. 63, third pair.

Common Laurel

The subjoined figures illustrate the structure of the bud of a Common Laurel (*Cerasus Laurocerasus*).

Here again the leaf commences as a small projection or lobe immediately below the growing-point. Very soon



COMMON LAUREL.

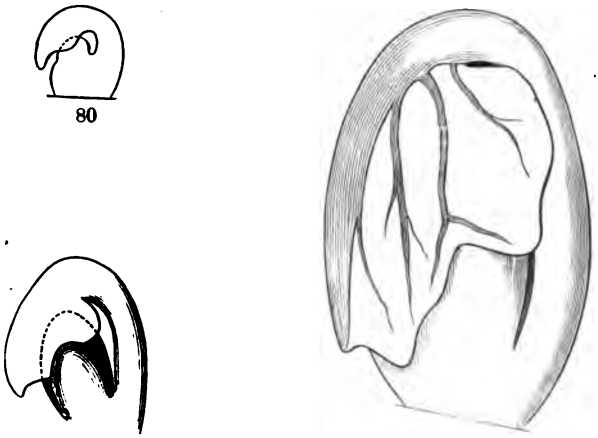
FIGS. 64–70, leaves and their stipules ; *s*, *s*, stipules ; × 10.
FIGS. 71–79, outer scales.

two other lobes appear at the base of the first (fig. 64, *s*, *s*). These are the stipules. They are at first much smaller than the leaf. By the time, however, that the leaf-blade has reached $\frac{1}{50}$th inch (fig. 67) the stipules have caught it up. They are more oval, more pointed, and bordered by a row of small projections. They continue to grow (fig. 68) more rapidly than the leaf-blade, and somewhat unequally (fig. 69), the larger one becoming rather more (fig. 70), the shorter one rather less, than double as long as the leaf-blade. Then comes a somewhat abrupt transition, and the outer scales do not, of course, correspond to stages in the development of a normal leaf. A rudimentary leaf, such as that in fig. 70, is followed by a scale of quite a different form: broader, wrapping round the bud, and consisting of three parts nearly but not quite equal in length, and separated almost to the base (fig. 71); the two outer pieces representing the stipules are rather broader than the central. In the next (fig. 72) the leaf-blade is rather longer than the stipules, and the common stalk or leaf-base is longer in proportion. This is still more the case in the next two (figs. 73, 74). In the twelfth (fig. 75) the leaf-stalk is abruptly truncated; and in the following the stalk and stipules are reduced to three small prominences. Finally, the outer scale is much shorter and broader in proportion (fig. 79).

THE TULIP TREE (*Liriodendron tulipifera*)

In the Tulip Tree the leaf commences as a slight projection immediately below the growing-point, and gradually widens into a ridge, the two ends of which eventually meet, forming a ring.

One part raises itself above the rest and forms the leaf-stalk; the two side pieces become the stipules. They grow upwards and inwards, finally forming a hood over the growing-point. About the time when the stipules meet the leaf-blade commences. It is at first a very narrow, delicate, hyaline membrane. The bud then assumes the appearance shown in fig. 80.

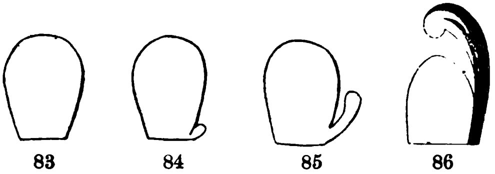


TULIP TREE (*Liriodendron tulipifera*).

FIG. 80.—Very young leaf and stipule, × 20. FIG. 81.—Do. do. second stage, × 20. FIG. 82.—Do. do. rather more advanced stage, × 20.

The next stage (fig. 81) shows the growth of the leaf-blade, which is more developed in fig. 82. Fig. 17, p. 14, shows how closely the young leaf fits in the hollow of the bud; while the final arrangement of the leaf in the bud is shown in figs. 17 and 18.

In the axillary buds, as a rule, the outer covering consists of two stipules, the rest of the leaf not being developed (fig. 83). Sometimes, however, at the base a small projection may be seen (fig. 84), which is a rudiment of a petiole. Sometimes this is rather more developed (fig. 85), and sometimes a rudimentary blade also appears (fig. 86).



Figs. 83–86.—Tulip Tree. **Outlines of different axillary buds.**

The reversal of the leaf in the bud, owing to the length and early development of the petiole, is very unusual. In *Amicia Zygomeris* the leaf is bent, but only forms a right angle with the petiole.

Rose

The leaf of the Rose (see *ante,* fig. 58, p. 46) is more complicated. It commences as a small knob at the side of, and immediately below, the growing-point. When this knob has reached a certain length it presents two lobes (fig. 87), which arise almost simultaneously.[1] The upper of these becomes one of the upper leaflets, the lower is one of the stipules. Almost immediately a third, and then a fourth, lobe make their appearance. The third is the rudiment of a leaflet of the second pair, the fourth of the third.

---

[1] According to Schacht, however, the stipule appears first.

Thus the stipule appears almost simultaneously with the first and upper leaflet, before any of the lower and later ones. These originate close above the stipules. Gradually, however, the petiole elongates, thus carrying the lower leaflets away from the stipule. De Candolle described the stipules as being connate

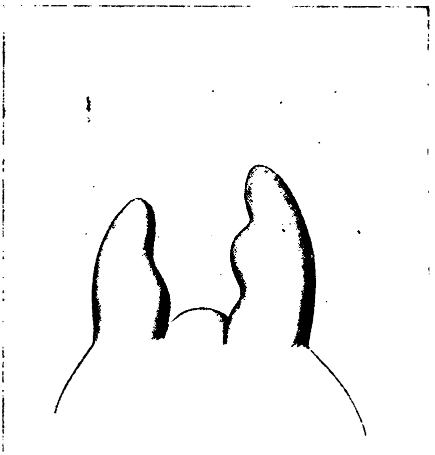


Fig. 87.—Growing-point of Rose with Two Leaves in successive Stages of Development. Highly magnified.

with the petiole. This, however, is not, I think, strictly correct. The true petiole is the leaf-stalk above the stipules. The winged part below is really a development of the leaf-base.

Adnate stipules, as these are called, arising from a similar development of the leaf-base, occur in many other cases, as, for instance, in some Lupins, Clovers, *Potentilla*, &c. That winged petioles are not always stipular is, however, shown by the case of *Lathyrus*; for instance, *L. silvestris*.

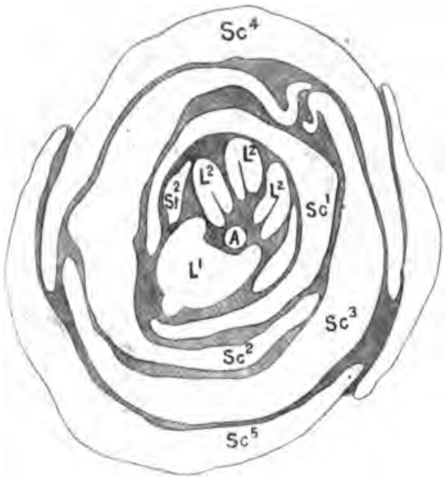
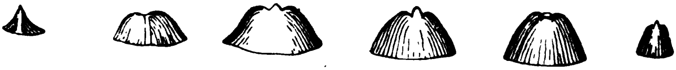


FIG. 88.—SECTION ACROSS THE BUD OF A ROSE.
A, growing-point; L^1, youngest leaf; L^2, three folded lobes of second leaf; St^2, stipules of second leaf; Sc^1-Sc^5, scales.

The rudimentary leaves in the Rose pass gradually into the bud-scales; the transition is not so abrupt as in the *Aucuba* or in Maples (fig. 8, p. 7).

If we examine a Rose-bud in winter, the first or outermost scale (fig. 89) is unequally triangular, as a rule acute, carinate, and small. The second one is very similar, at least in the case of lateral buds. The third scale (fig. 90) is much larger, and rounded at the apex, or occasionally emarginate by the breaking away of the tip, and more or less strongly carinate. The fourth scale (fig. 91) is twice as large as the third, broad at the apex and tridentate, the middle tooth representing the petiole, and the more obtuse lateral ones the stipules.



89 90 91 92 93 94

BUD-SCALES OF ROSA CANINA, × 2.
FIG. 89, first scale; FIG. 90, third do.; FIG. 91, fourth do.; FIG. 92, fifth do.; FIG. 93, sixth do.; FIG. 94, ninth do.

The fifth scale (fig. 92) is rather narrower, but covers about half of the bud, and the middle tooth is slightly the longest. The sixth scale (fig. 93) is the longest, surmounting the bud, and folded round it so as to cover about three-fourths of its surface; the three teeth are about equal in length. From this point onwards the scales get rapidly shorter and smaller. With this difference the seventh and eighth scales are similar to the sixth; they are rolled round the bud, covering about seven-eighths of its surface, and overlapping at their apex. The middle tooth at the apex has slightly increased in length. This is even more evident in the ninth (fig. 94) and tenth scales, both of which are small.

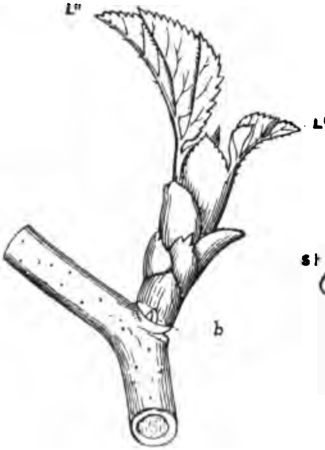


FIG. 95.

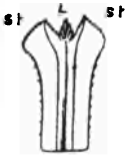


FIG. 96.

ROSA CANINA.

FIG. 95.—Stem bearing expanding lateral bud, × 2; one scale has fallen, revealing its axillary bud (*b*); five scales are shown, and two of the first leaves. Sketched March 24.

FIG. 96.—Uppermost scale, immediately preceding the first true leaf, × 2; L, undeveloped blade; *st*, *st*, stipules.

The eleventh scale may be described as the first normal leaf, though still rather imperfect. The leaflets are represented by small or narrow teeth, crowded together. The stipules are now well developed, and much larger in proportion to the rest of the organ than in previous cases. The second leaf, occurring at the twelfth node, has a more elongated lamina, though still rather imperfect. The stipules are well developed, and as in the previous case, they cover about three-fourths of the bud. Succeeding ones are very minute, and appear to be perfect leaves. No free petiole is to be seen at this stage of the bud in winter, the stipules being adnate along the whole length of the midrib, so that the lamina of the leaf is sessile.

The above description was made from an average bud on a strong shoot. Buds on weak shoots have fewer scales. Buds examined in January were still dormant, or nearly so; and this applies to most or all of the British Roses. Some exotic species, such as *Rosa indica*, *R. multiflora*, and others of that type, are almost bursting into leaf at the same date, if the weather is at all mild. The appearance of a developing bud in spring, with one leaf nearly expanded, is given in fig. 95.

In the Rose, as we have seen, the development of the leaflets proceeds from above downwards, the upper leaflets being the older. This mode of growth, therefore, has been termed ‘basipetal’ (fig. 97). The same sequence is followed by many other *Rosaceæ*, *Valeriana*, *Melianthus*, *Reseda*, Grasses, *Cyperaceæ*, Lilies, Orchids, and probably all Monocotyledons.

On the other hand, there are also species in which the reverse takes place—*i.e.*, in which the lowest lobes are the oldest, and others are developed upwards, *i.e.*, are basifugal (fig. 98), as in the Pea, *Ailanthus*, *Mahonia*, &c.

A similar difference in the mode of growth may be shown to occur even when there are no leaflets. Thus, Steinheil made a nick with a knife on a young growing leaf of *Mesembryanthemum*, half way up, and found that in the full-grown leaf it was much nearer the apex than the base. *M. deltoideum* has a number of small fleshy points, especially one at the summit, and two at each side. These are in proportion much nearer the base in the young than in the full-grown leaf. Again, in *Urtica biloba* the notch at the apex of the leaf, from which the species takes its name, reaches in the young leaf to the centre, but in the full-grown leaf only a third or a quarter of the length. In pinnate leaves the insertions of the pinnæ are, as Steinheil says, marks written by Nature on the leaves, and when, as in many cases, they are nearer together at the base, the upper leaflets are the older and the lower ones younger. Thus, a growing leaf of *Asclepias syriaca* may have six

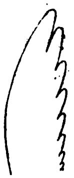


FIG. 97.—TO ILLUSTRATE BASIPETAL GROWTH.

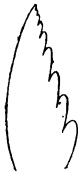


FIG. 98.—TO ILLUSTRATE BASIFUGAL GROWTH.

pairs of lateral nerves in the upper half of the leaf and eighteen in the lower. In the perfect leaf, on the contrary, each half bears thirteen.

In some cases, however, the growth of the leaf as a whole and that of the separate leaflets follows different lines.

Trecul, moreover, has shown that the development of leaves cannot in all cases be brought under these two categories. In *Centaurea*, for instance (fig. 99), the central lobe is formed first, and others appear successively, both upwards and downwards.

There has been much difference of opinion whether any, and, if so, what, other modes of development exist in addition to those already mentioned, but from my special point of view it is not necessary to go into this question.

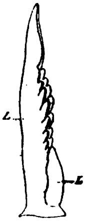


FIG. 99.—YOUNG LEAF OF CENTAUREA SCABIOSA, × 14. The larger leaf embraces a younger one at its base.

GALIUM

The following figures, after Eichler, illustrate the development of the leaf in the Ladies' Bedstraw (*Galium Mollugo*). Fig. 100 gives a vertical view of the tip of a shoot. Round the central growing-point is a nearly circular ridge. Immediately below this is another ridge, which shows a number of small eminences—two larger, right and left, which are the rudiments of the leaf-blades; and four smaller, at the four corners, which represent the rudiments of the four leaf-like stipules, two belonging to each leaf.

Fig. 101 represents a rather more advanced stage, in which two other knobs (one of which is already indicated at the top of the left-hand figure) have made their appearance, which complete the ring of eight so-called leaves. This figure is taken from a lower node, the leaves of which will be at right angles to those of the previous node. Hence the leaf-rudiments which were to the right and left in the first figure now stand above and below, while the last added rudiments stand right and left. The four true stipule-rudiments still occupy the corners.

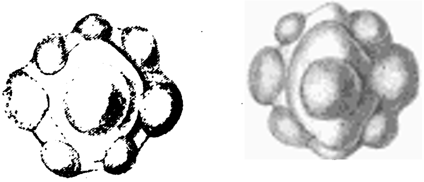


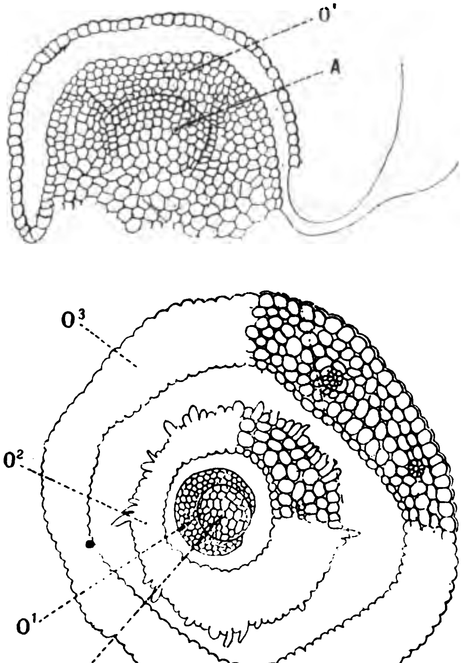
Fig. 100. Fig. 101.

Leaf Development in Galium Mollugo. Highly magnified.

Some leaves have what is known as an 'ocrea.' This is a sheath which, taking its origin at the base of the leaf, surrounds the stem above it for a greater or less distance. Ocreas occur in the Plane, Dock (*Rumex*), *Polygonum*, Pondweed (*Potamogeton*), &c.

THE PLANE (PLATANUS)

The leaf of the Plane originates in a ridge which runs round the whole axis immediately below the growing-point.



FIGS. 102, 103.—LEAF DEVELOPMENT IN PLATANUS OCCIDENTALIS.

The upper figure shows the growth of the first leaf-ridge (o^1) round the growing-point, A. The ridge is not yet complete, being still open towards the front. The outermost row of cells is the inner surface of the base of the protecting leaf-stalk.

The lower figure (transverse section) shows three leaf-ridges (o^1, o^2, o^3) surrounding the growing-point, A. The youngest ridge (o^1) is still incomplete.

At one place it raises itself more than elsewhere, and develops two side processes—the two primary leaf-lobes. These soon develop two side lobes. In the meanwhile the conjoined stipules gradually close over the growing-point, and finally cover it entirely. They do not, however, coalesce in the centre, but only touch. At a later period the edges turn outwards and assume a leaf-like form (fig. 136).

The account given by Benjamin (10) is somewhat different, but I believe that of Eichler, confirmed by Mikosch, is substantially correct.

POLYGONUM

In *Polygonum* also the leaf arises as a small projection just below the growing-point, and gradually extends round it.

This ring, which originates the primordial leaf, is higher at one place, which will develop into the leaf-blade. The rest of the ring grows and extends across the base of the leaf until it entirely surrounds the growing-point, forming the ocrea, and often projects some way beyond the growing-point. It completely covers the bud, which, however, eventually forces its way through.

VERNATION

The attitude of leaves in their very young stage is termed by botanists 'vernation.' Some lie flat, as, for instance, the Mistletoe and *Mesembryanthemum.* This is usually the case with fleshy leaves. Among the most common modes of folding are the following, which are illustrated by the diagrams in fig. 104.

1. Conduplicate: when folded lengthways, doubled up on the midrib, as in the Rose, Bramble, Tulip Tree (fig. 104, A).

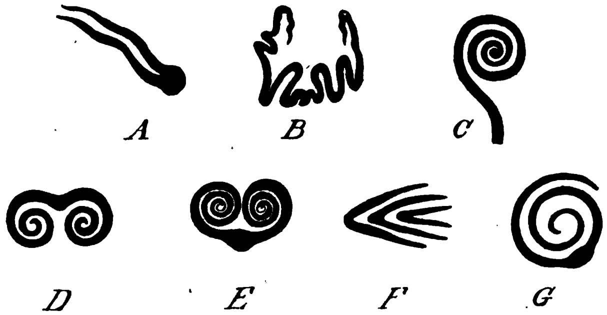


Fig. 104.—Diagrams illustrating Vernation.

2. Plicate, or plaited: when folded like a fan on the ribs, as in the Maples, Currant, and most palmate leaves (fig. B).

3. Circinate: when coiled like a crozier, as in the Ferns, *Drosera*, &c. (fig. C).

4. Revolute: when rolled backwards from the margins, as in Azalea, Rosemary, and many plants of hot, dry places (fig. D).

5. Involute: when rolled inwards from the margins, as in Violets, Water Lilies, &c. (fig. E).

6. Equitant: when the leaves are folded one over the other, as in Grasses, Sedges, Iris, and many other Monocotyledons (fig. F).

7. Convolute: when rolled up from one margin—*i.e.* one margin within, the other without the coil, as in the Cherry, Peach, Pea, Vetch, &c. (fig. G).

There are sometimes considerable differences between nearly allied species; and in some cases the outer and inner leaves of the bud assume different positions.

The conduplicate arrangement seems to follow naturally from the mode of development described on p. 47. The rudiment of the leaf, spreading more or less round the growing-point, assumes a hollow form, and when it rises above the central axis would thus become folded on itself.

In pinnate leaves generally, as in those of the Rose, each leaflet is conduplicate.

In palmate leaves the folded arrangement is that naturally best calculated to enable them to fit into the bud.

The involute and revolute types perhaps have reference to the later life of the leaf, as affording a certain protection against too rapid transpiration.

The equitant type follows naturally from the mode of growth of many Monocotyledons.

Leaves of the same form may be folded in very different ways, and it is seldom that the same plan runs through a whole family, at least among Dicotyledons.

The leaves of water-plants are as a rule flat or rolled, not folded.

The consistence of the leaf exercises much influence, for thick, leathery, or fleshy leaves, such as those of Mistletoe (*Viscum*), Aloe, many Crassulas, Saxifragas, &c., naturally are as a rule flat; sometimes rolled; but rarely folded. Pinnate and trifoliate leaves are generally folded.

In Monocotyledons the leaf rises as an elevation immediately below the growing-point, gradually surrounding part of the stem, and highest at the point opposite the opening. The ridge extends until it forms a sheath more or less completely surrounding the stem.

The leaves of Palms and Aroids develop in a manner very unlike that usual among Dicotyledons. The leaf originally forms a continuous blade, which is much folded, and subsequently divides. According to Eichler, this is effected by a process of disorganisation at the edge of the fold. A similar process occurs in the segmentation of the originally entire thallus of species of *Laminaria*, a common genus of brown seaweed. Naumann (11), on the contrary, maintains that the cells along the line of the fold detach themselves and diverge from one another. I believe, however, that Eichler's view is correct.

CHAPTER IV

ON THE PROTECTION OF BUDS

YOUNG leaves are extremely delicate. They require protection from too great heat, cold, dryness, moisture, and light, as well as against the attacks of animals.

For this purpose they are often provided with a covering of more or less woolly hair, which generally drops off when it has served its purpose.

In other cases the outer envelopes of the bud are specially modified for the purpose.

As Grew (12) quaintly says: 'According to the Form and Foulding of every Leaf or Germen, is its Protection order'd; about six ways whereof may be observed; sc. by Leaves, Surfoyls, Interfoyls, Stalks, Hoods, and Mantlings. To add to what we have above given, one or two Instances. Every Bud, besides its proper Leaves, is covered with divers Leafy Pannicles, or Surfoyls; which, what the Leaves are to one another, are that to them all. For not opening except gradually, they admit not the Weather, Wet, Sun or Air, to approach the Leaves, except by degrees respondent, and as they are gradually inur'd to bear them. Sometimes, besides Surfoyls, there are also many Interfoyls set betwixt the Leaves, from the Circumference to the Center of the Bud; as in the Hasel.'

Here he uses the term 'Surfoyls' for the outer scales, whatever their true character may be. His 'Interfoyls' are stipules.

Besides the protection afforded by actual coverings, the opening buds in many cases guard themselves, to some extent, at any rate, by assuming either an erect position, as in the Whitebeam (*Pyrus Aria*) (Pl. II. fig. 5), *Acer platanoides* (Pl. II. figs. 2–4), and, I believe, most shrubs with opposite leaves; or a drooping attitude, as in the Lime (*Tilia*) (Pl. I. figs. 1–3), Beech (*Fagus*) (Pl. IV.), Hazel Nut (*Corylus*), Elm (*Ulmus*) (Pl. III.), &c. The great leaves of Palms are at first vertical.

One advantage thus gained is that the radiation is much less than it would be if the leaves were to assume at once their permanent horizontal position. Darwin has shown that this position really does tend to check the effect of radiation. Our experiments, he says, 'show that leaves compelled to remain horizontal at night suffered much more injury from frost than those which were allowed to assume their normal vertical position.'[1]

'We exposed on two occasions during the summer to a clear sky several pinned-open leaflets of *Trifolium pratense*, which naturally rise at night, and of *Oxalis*

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[1] *Movements of Plants*, p. 286.

purpurea, which naturally sink at night (the plants growing out of doors), and looked at them early on several successive mornings, after they had assumed their diurnal positions. The difference in the amount of dew on the pinned-open leaflets and on those which had gone to sleep was generally conspicuous, the latter being sometimes absolutely dry, whilst the leaflets which had been horizontal were coated with large beads of dew. This shows how much cooler the leaflets fully exposed to the zenith must have become than those which stood almost vertically, either upwards or downwards, during the night.

'From the several cases above given there can be no doubt that the position of the leaves at night affects their temperature through radiation to such a degree that, when exposed to a clear sky during a frost, it is a question of life and death.'[1]

It is probable, however, that in some cases, at any rate, this position is assumed as a protection against too intense light.

The principal modes by which buds are protected are:

1. By the expanded base of the preceding leaf.
2. By scales which represent modified outer leaves, as in Willows, Ash.
3. By the outer leaf-stalks, as in Maples, Ash.
4. By stipules, as in the Beech, Oak.

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[1] *Loc. cit.* p. 293.

5. By the two connate stipules of a leaf, as in the Elm, Spanish Chestnut.
6. By two connate stipules belonging to different leaves, as in the Hop.
7. By spines.
8. By furry hair.
9. By gum, resin, or mucus.

In considering the protection of buds in their youngest stages we must distinguish between two different cases: the first, where the young bud as a whole is protected by older organs; and the second, when the future leaves are protected by the outer bud-scales.

The cases in which the young bud is protected by older organs may be divided into four principal categories:

1. Those in which the protection is mainly afforded by leaf-blades.

2. Those in which the protection is mainly afforded by the petiole or by the leaf-base.

3. Those in which the protection is mainly afforded by stipules.

4. Those in which the protection is mainly afforded by hairs.

PROTECTION BY LEAVES

In hot countries, where the young bud principally requires protection from the scorching rays of the sun, this is often effected by their simply lying under the shelter of older leaves. A good example is afforded by *Uvaria purpurea*, which has been described and figured by Mr. Potter (1, 349). ‘A front and also a back view of a shoot of this plant are shown in figs. 105 and 106, where fig. 105 is the front view and fig. 106 the back view of a similar shoot. The shoots themselves are in this plant slightly inclined to the vertical, so that by this means the younger leaves are protected from the sun's

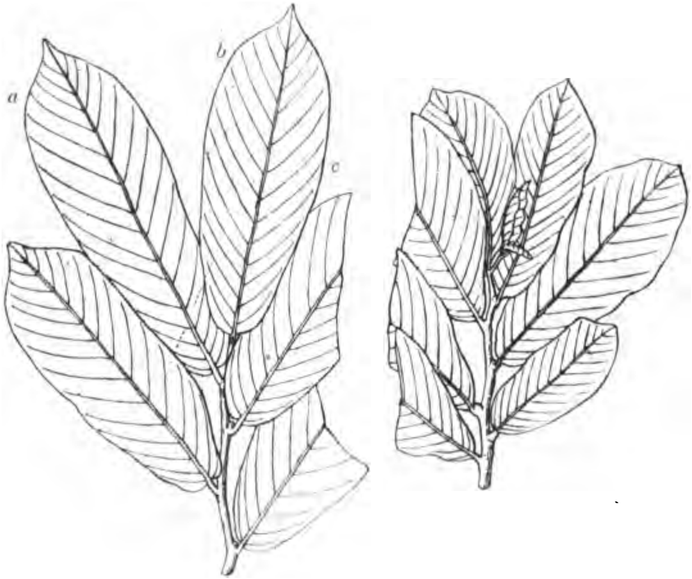

FIG. 105. FIG. 106.

SHOOT OF UVARIA PURPUREA.
FIG. 105, front view. FIG. 106, back view.

heat. On examining the front view (fig. 105), we see that the three leaves *a*, *b*, *c*, are so arranged that they completely cover over the growing-point and its younger leaves, so that these latter are completely shielded; while the back view (fig. 106) shows how the younger internodes, with their smaller leaves, are hidden behind the large leaves. The young leaves as they attain to their mature size assume the same relative positions, and so protect other young leaves, and so on.' I have already referred (*ante*, pp. 4, 5) to the cases of Begonia and Rhubarb.

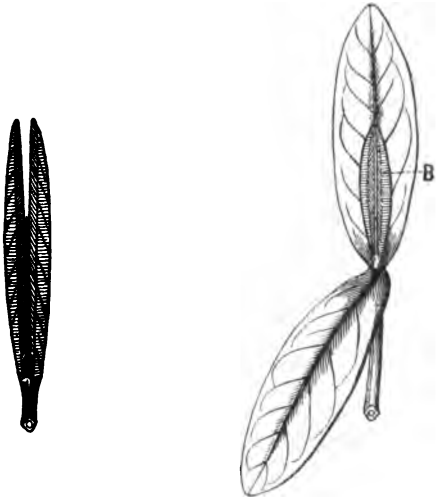

Fig. 107. Fig. 108.

Shoot of St. John's Wort (*Hypericum*), showing protection of the young pair of leaves (B).

Fig. 107.—Side view. Fig. 108.—Front view.

In other cases the leaves form successively a more or less complete covering for those that follow, as, for instance, in the St. John's Wort (*Hypericum*) (figs. 107, 108).

In the Common Barberry (*Berberis vulgaris*) (fig. 109) the primary leaves are changed into spines. The bud, however, in the axils of these spinose leaves develops into a short axis with foliage leaves. This is why the leaves in this species are collected in tufts.

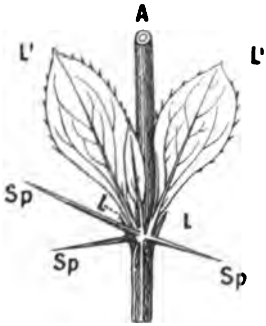

FIG. 109.—SHOOT OF BARBERRY (*Berberis vulgaris*), showing three spines, *Sp*, representing the leaf. Nat. size.

A, stem; L, L, leaves on a lateral shoot arising in the axil of the spiniform leaf, and themselves reduced to short, subulate spines; L′, L′, more perfect leaves on the same lateral shoot.

In *Azima tetracantha* (a member of the *Salvadoraceæ*, a small tropical family of Dicotyledons) the axillary buds are rather remarkable. What appear to be two spines, situated in the axil of the leaf are really the first pair of leaves of the axillary shoot. In their early stages they are erect, closely applied, and very short, but when fully developed they become hard, spiny, and diverging. Their foliar nature is further indicated by the fact that a slender groove runs along the opposing faces from apex to base, where there is a deeper cavity, as if a sheath were attempted. They are also articulated with the stem. The second and third pairs of leaves on the axillary shoot (when the latter develops) are reduced to scales, which decussate with the spines. True leaves follow the scales.

PROTECTION BY THE LEAF-BASE OR THE LEAF-STALK

The axillary buds are thus protected in most Composites, Umbellifers, in the whole family of the *Caryophyllaceæ* (Pink family), except *Spergula* and *Spergularia*, in the Gentians, and many other families.

In all these species the base of the petiole is more or less dilated, so as the more effectually to protect the bud.

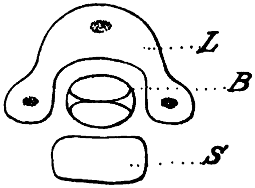

FIG. 110.—SECTION ACROSS THE STEM OF A WALNUT. *L*, petiole ; *B*, bud ; *S*, shoot.

Fig. 110 represents a section across the stem of a Walnut (*Juglans nigra*). It shows the bud, *B*, lying between the stem, *S*, and the dilated base of the leaf-stalk, *L*. The protection is more complete than the figure indicates, because in nature the parts touch, while for clearness a small space has been left between them in the illustration.

In the Box Elder (*Negundo aceroides*) (figs. 111, 112), a near ally of the Maples, the base of the petiole is also widened, concave, almost covering the axillary bud, and attached to the axis by a wide and deeply horseshoe-shaped base. The interior of the concavity is densely lined with white silky hairs, which almost completely surround the axillary bud, keeping it safe and comfortable till the fall of the leaf. The terminal bud nestles in the cavity between the petioles of the youngest expanded or expanding pair of leaves. The petioles of the latter remain erect for a considerable time, and being closely applied face to face, they completely cover and protect the bud. When growth becomes arrested for the season the terminal bud attains some size, so that its tip projects beyond the cavity of the petioles. By this time, however, the scales of the winter-bud are sufficiently hardened to escape harm and protect the younger members.

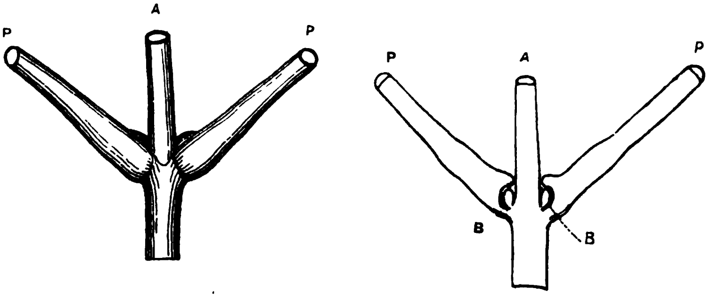

FIG. 111. FIG. 112.

NEGUNDO ACEROIDES. Nat. size.

FIG. 111.—Portion of shoot (A) with the bases of the two opposite leaf-stalks (P).
FIG. 112.—Vertical section of same, showing the axillary buds (B) sheltered in the hollowed base of the leaf-stalk.

In *Sophora japonica* (fig. 113), one of the *Leguminosæ*, the terminal bud is thickly covered with brown hairs, and is also protected by the crowding of the leaves and the stipules. The latter are narrowly linear or setaceous and caducous, *i.e.*, falling early. The axillary bud is entirely protected by the swollen, fleshy base of the petiole. The resting bud remains very small during winter, and consists of leaves and stipules, crowded together, and densely covered with short, brown hairs.

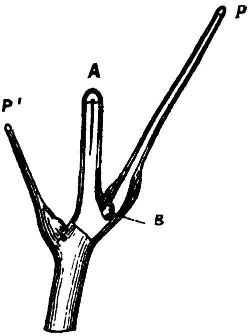

FIG. 113.—SOPHORA JAPONICA. Nat. size.

Two nodes of a stem, the lower showing the base of the petiole (P′) with the small round scar of the fallen stipule. In vertical section above, the upper node showing the axillary bud (B) completely covered by the thickened, fleshy base of the petiole (P″).

In *Citharexylum quadrangulare* (fig. 114), belonging to the *Verbenaceæ*, an exstipulate family, the axillary buds are completely covered by the concave pedestal.

The terminal bud in the growing state consists of leaves partly conduplicate, then involute at the margins, and placed face to face, but not overlapping or interlocking with one another. The leaves attain some size before expanding, and each pair covers the next younger pair.

In some cases the petiole forms a regular arch over the bud, as, for instance, in *Rhus glabra* (fig. 115). Additional protection is also afforded by hairs, both on the bud and on the under side of the cup formed by the petiole.

In these cases the overarching tissue belongs entirely to the petiole. In others the stem also projects outwards, and thus makes the protection more complete.

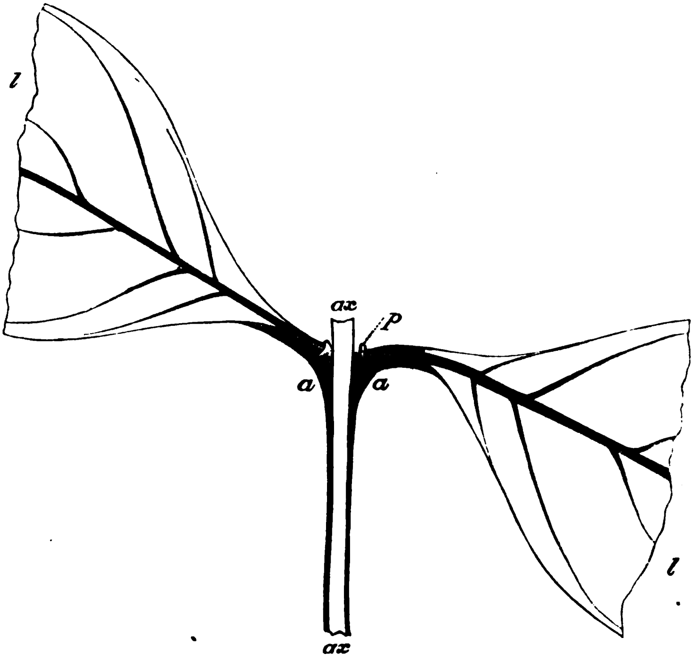

FIG. 114.—CITHAREXYLUM QUADRANGULARE. Nat. size.
ax, *ax*, axis of shoot with portions of a pair of leaves; *a a*, articulation of the leaves, *l*, *l*, to the persistent sheathing pedestals, one of which, *p*, is slightly opened to show the axillary bud it covers.

In *Kalmia latifolia*, for instance (figs. 116–119), the axis of every shoot produces an outgrowth opposite the dilated portion of the petiole.

This is carried still further in *Actinidia colomicta* (fig. 120), where, as Feist (13) has shown, the bark of

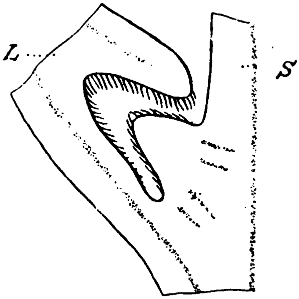

FIG. 115.—RHUS GLABRA.
Section through a bud shortly before the leaf falls. *S*, stem; *L*, base of leaf-stalk. Enlarged.

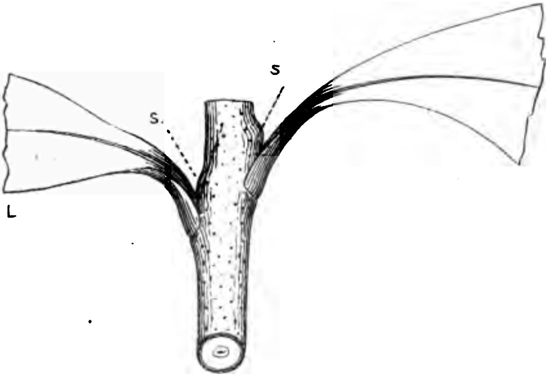

FIG. 116.

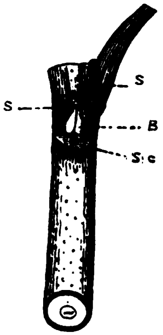

FIG. 117.

SHOOT OF KALMIA LATIFOLIA, × 2.

FIG. 116.—S, swelling of the stem just above the base of the leaf (L), between which and the leaf-base the bud is sheltered.
FIG. 117.—Another view. *Sc*, scar of leaf; S, swelling; B bud.

the stem throws out a process which almost meets that of the petiole.

A still further advance in the efficient protection ot the bud by the petiole occurs in those species—as, for instance, in the Plane (*Platanus*, fig. 7, p. 6)—where the lower part of the petiole has closed completely round the bud, covering it like an extinguisher: in such species the bud is not where we should naturally expect to find it, namely, in the angle between the petiole and the stem, but enclosed in the base of the petiole itself. For such buds the term 'intrapetiolar' was proposed by Benjamin, who first called special attention to them.

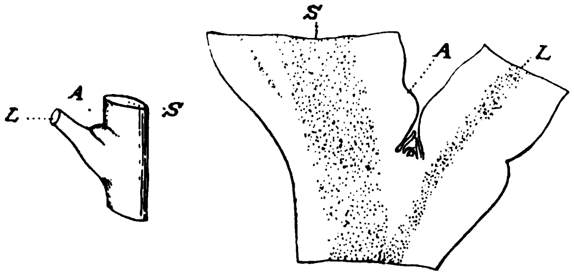

Fig. 118. Fig. 119.

KALMIA LATIFOLIA.

Small piece of shoot, entire (fig. 118), and enlarged in vertical section (fig. 119). *S*, stem; *A*, swelling in stem; *L*, leaf-stalk.

In these cases, however, the protection seems to fail just when it might seem to be most needed. At the approach of winter the leaf falls off, leaving the bud uncovered. Being thus thrown on its own resources, it is compelled to protect itself, and we shall presently consider the various plans which have been adopted with this object. By that time, indeed, the tissues have become hardened, and more capable of resistance to external influences.

It would seem, however, that it would have been an advantage if the petiole of the Plane, instead of detaching itself at the base, had separated higher up, thus leaving a cap to protect the young bud.

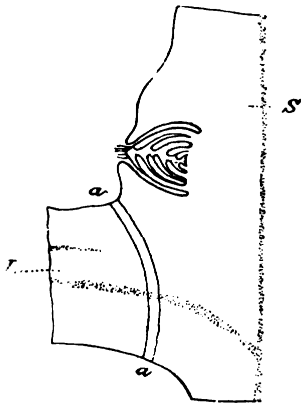

FIG. 120.—ACTINIDIA COLOMICTA. Section shortly before the leaf falls ; bud completely covered. *S*, stem ; *L*, leaf ; *a a*, plane of separation of leaf.

This, in fact, does happen in other cases. Thus, in *Philadelphus* (the Sweet Syringa of our gardens and shrubberies), in *Actinidia colomicta* (fig. 120) (according to Hildebrand), *Robinia*, and some other species, if we examine a shoot, we shall at first see no traces of buds.

Fig. 121 gives a section through such a twig of *Philadelphus* at one of the joints, on the right side before, and on the left after, the fall of the leaf.

Fig. 122 gives a section of one side of a similar knob, more magnified ; *a a* shows the line along which the leaf *L* will detach itself, leaving a pedestal, which completely protects the bud, by the growth of which it is eventually pushed off. Intrapetiolar buds also occur in *Skimmia japonica*, *Xanthoxylon Bungei*, &c.

It will be observed that the leaf-stalk does not detach itself, as in the Plane, at the base, but a little higher up, thus leaving a sort of cap, which for clearness is represented in the figure as a little detached, but which in nature fits closely over the bud, and remains till spring, when it is pushed off by the expanding leaves. The cavity is also lined by a thick felt of brown, hollow, air-containing hairs, which no doubt serve as a very effective non-conductor of heat. If the brown cap is removed the green bud will be found snugly ensconced under it.

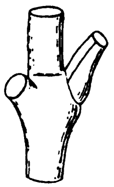

Fig. 121.

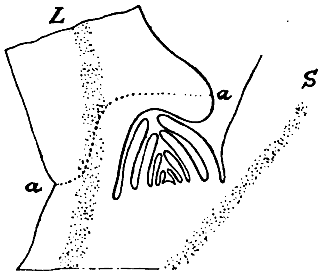

Fig. 122.

PHILADELPHUS CORONARIUS.

Fig. 121.—Small piece of shoot. Fig. 122 —Portion of fig. 121 much enlarged; *a a*, line along which the leaf detaches itself.

The bud in the *Robinia*, like that of *Philadelphus*, is completely covered by the base of the petiole.

If we examine the scar left by the leaf, we shall find, as pointed out by Benjamin, a broad, irregular, somewhat pointed hump, from each side of which the two stipules project as spines. The bud is not visible, but occupies a hollow in this eminence, which is, in fact, formed by the persistent base of the petiole. The cavity, as in *Philadelphus*, is lined by a thick felt of brown, hollow, air-containing hairs.

The protection of the bud in *Berberis* resembles that in *Robinia*.

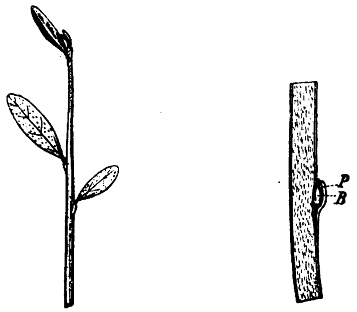

FIG. 123. FIG. 124.

SHOOT OF SPARTIUM JUNCEUM.

FIG. 123.—Reduced one-half. FIG. 124.—Part of same shoot, to show the bud protected by the pedestal of the fallen leaf; nat. size. *B*, bud; *P*, persistent pedestal of leaf.

In *Spartium junceum* (figs. 123, 124) there are no stipules, but the bud is protected by the enlarged, concave, persistent pedestals of the last year's leaves.

A similar arrangement occurs in the Broom (*Cytisus scoparius*) and other species of *Cytisus*, while the terminal bud is protected by two small scales and a dense covering of hair.

In *Genista tinctoria* the stipules are subulate-triangular, acute, short, and seated on the persistent and elongated pedestal of the leaf. The winter-bud is also protected by scales, consisting of reduced leaves, on which the stipules are scarcely perceptible. In *Genista antarctica* and *G. sagittalis* the stipules are similar but even more minute. In *G. virgata* the shoots die at the tips, so that there are no terminal buds. The pedestals are densely lined with hairs on the inner surface.

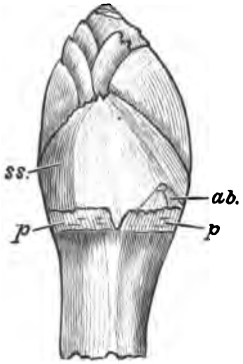

FIG. 125.—WHITEBEAM (*Pyrus Aria*). WINTER-BUD. *p p*, persistent base of fallen petioles; *ab*, axillary bud; *ss*, second scale.

In the Whitebeam (*Pyrus Aria*) (fig. 125) also the outer scales are the base of the last year's leaf-stalks. A similar arrangement occurs in *Clematis crispa*.

Protection by pedestals occurs in various other members of the families *Rosaceæ*, *Pomaceæ*, *Amygdalaceæ*, &c. It is by no means confined to species with intrapetiolar buds.

In these cases the bud is protected by the leaf-stalk, or the leaf-base of the leaf in the axil of which it is situated.

PROTECTION BY STIPULES

We now come to cases in which buds are protected by the stipules of the mother-leaf. This may be said to be the function which stipules most frequently perform. See, for instance, Plates I., III., IV.

As a general rule such stipules fall with the leaf to which they belong. In some cases, however, as in *Petteria* (figs. 129, 130), they persist, and thus form a more effective, or at least more permanent, protection to the young bud.

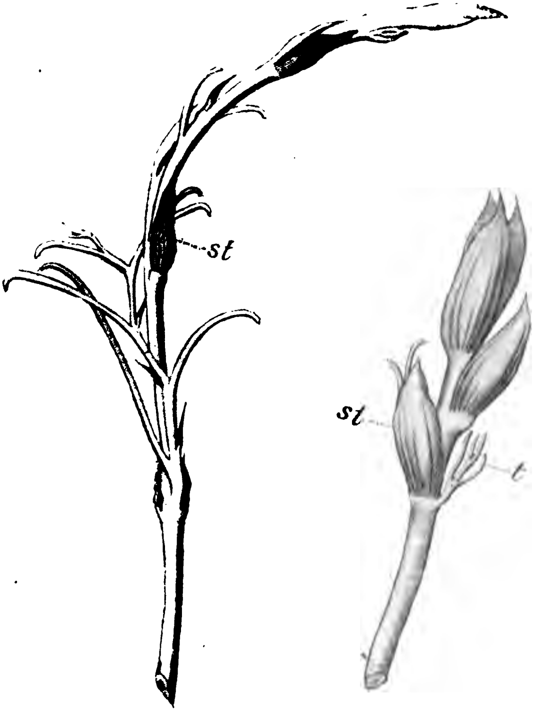

Fig. 126.—Young Shoot of Virginian Creeper, × 2.
st, stipule ; *t*, tendril.

There are, moreover, some cases in which stipules are developed so early that they serve not only to protect the younger leaves, but even the blade of the leaf to which they belong, as, for instance, in the Common Pea (fig. 26, p. 23), *Lathyrus maritimus* (fig. 296, p. 175), &c., Virginian Creeper (fig. 126), Vine (figs. 127, 128), Hop (fig. 48, p. 34). These will be alluded to in a subsequent chapter.

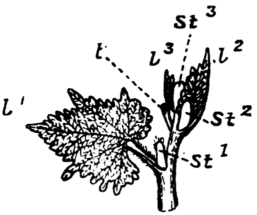

FIG. 127.

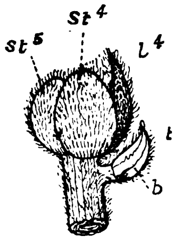

FIG. 128.

VINE (*Vitis vinifera*).

FIG. 127.—Tip of growing shoot, nat. size; l^1, l^2, l^3, three young leaves in order of succession; St^1, St^2, St^3, one of the pair of stipules belonging to each of the three leaves; *t*, tendril with its bract removed, showing the first fork.

FIG. 128.—Apical bud after removing the three leaves shown in fig. 127, × 5; l^4, the fourth leaf in succession; St^4, one of the stipules belonging to l^4; St^5, a stipule belonging to the fifth leaf; *t*, tendril almost enclosed in its bract; *b*, the bract, a modified leaf with three nerves in the sheathing base, which appears to consist of stipules adnate to the base of the petiole.

In *Petteria ramentacea* (figs. 129, 130) the stipules are at first small and obtuse. They have a covering of hair, and are axillary and slightly connate. The leaves are deciduous, but their stipules are persistent, and swell up or grow to considerable size, becoming thick and fleshy. Every lateral bud is, therefore, completely covered and effectually protected by the pair of stipules belonging to the leaf of the preceding year. These stipules, as well as the persistent pedestal of the leaf to which they are attached, are densely lined on the inner face with pale brown hairs like a thick fur, while they are glabrous and dull olive-green externally.

In *Guaiacum officinale* (figs. 131, 132) the stipules are axillary and connate into a rounded piece on each side of the stem on which they are inserted, covering the space between the petioles, but quite free from them. They persist even after the leaves have fallen, and become only gradually broken away from the top downwards.

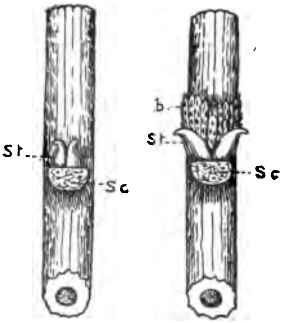

FIG. 129. FIG. 130.

PETTERIA RAMENTACEA.

FIG. 129.—Portion of shoot in winter, × 2. FIG. 130.—Ditto in spring, × 2. *Sc*, scar of fallen leaf; *St*, stipules completely covering the bud in fig. 129, in fig. 130 pushed aside by the developing bud (*b*).

In *Gardenia florida* (fig. 133) also the four stipules of the two opposite leaves are connate, and form a sheath, which encloses the younger parts of the bud.

In *Alstonia scholaris*, belonging to the *Apocynaceæ*, the leaves (fig. 134) are whorled at the apex of each shoot in groups of six to nine, narrowly oblong-elliptic, narrowed to both ends, but obtusely pointed.

The short petioles are semi-terete, flattened above, and furnished with a ligule or outgrowth from the base of the upper face, protecting the bud. This ligule is triangular, obtuse, pale green, 1·5–2 mm. long; collectively they form a whorl, covering all but the extreme apex of the bud. (See also 14.)

In *Spergularia rubra* (fig. 135) the leaves are opposite, long, narrow, fleshy, and somewhat flattened above. The stipules[1] are scarious, inserted at the node just beneath the leaves, so that they pass round the back of the latter, completely enclosing them in bud, and covering their bases even when fully developed. This is a most unusual arrangement. The stipules are also

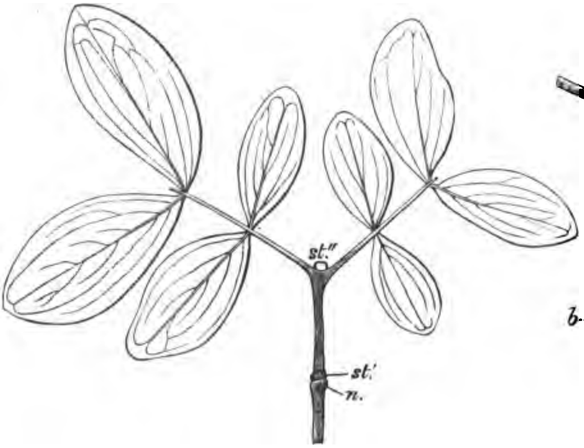

Fig. 131

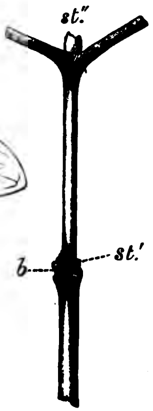

Fig. 132

GUAIACUM OFFICINALE.

Fig. 131.—Terminal shoot, nat. size; *n*, node; *st'*, connate stipules; *st''*, connate stipules covering the terminal bud.

Fig. 132.—Terminal shoot with lamina of leaves removed, x 2; *st' st''*, stipules as in fig. 131; *b*, lateral bud.

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[1] See Dickson, *Journ. Bot.* 1878, p. 316.

connate at the base, with an interpetiolar, free, ovate, acute piece, which is sometimes entire, sometimes divided at the apex into two or three setaceous teeth, as if these free portions consisted of one stipule from each leaf united. These stipules are very advanced in bud, and evidently attain full size long before the expansion of the leaves, many pairs of which they completely cover and protect. They are persistent, covering the bases of the leaves when full grown. They thus pro-

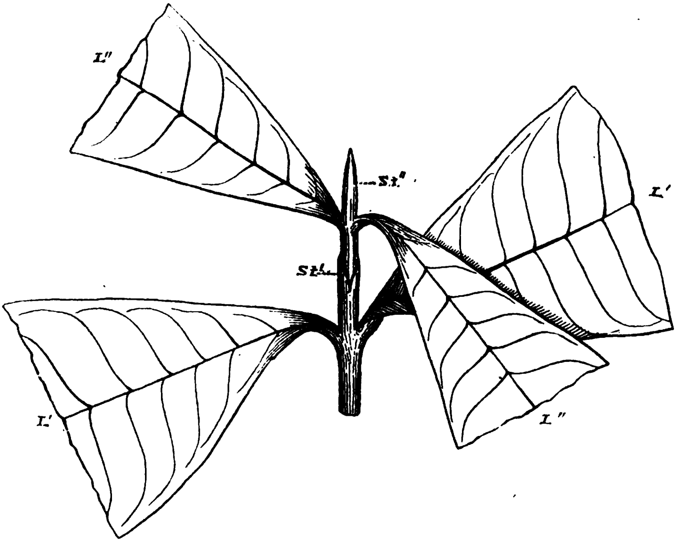


FIG. 133.—END OF SHOOT OF GARDENIA FLORIDA. Nat. size.

L′, *L′*, a pair of leaves with their connate stipules, *St′*, showing the fissured side only; *L″*, *L″*, the youngest unexpanded pair of leaves, with their stipules (*St″*) completely investing the terminal bud.

tect the terminal and axillary buds, the latter being very freely produced.

The stipules in this case may be compared to the ocreas or sheathing and scarious stipules of the *Polygonaceæ*. The stipules of the latter are, however,

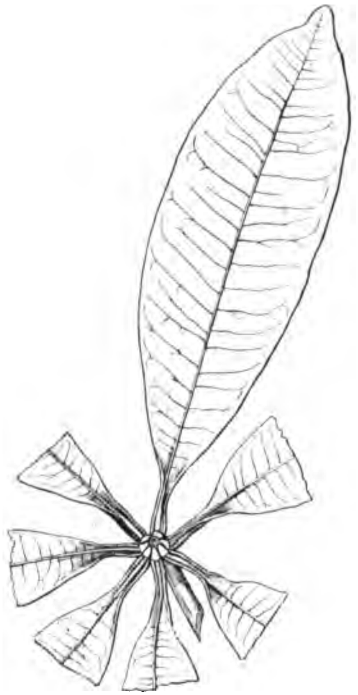


FIG. 134.—ALSTONIA SCHOLARIS. Terminal whorl of leaves to show ligules covering the bud. Reduced about one-half.

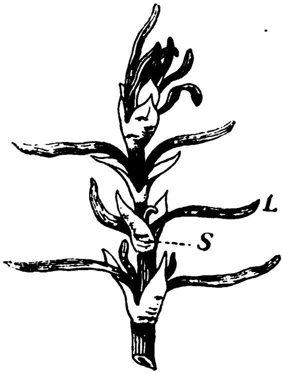


FIG. 135.—SPERGULARIA RUBRA, × 3. *S*, stipule ; *L*, leaf.

continuous with the edges of the petiole, which appears as a strong midrib to the sheath; while those of *Spergularia* are perfectly free from the leaves.

PROTECTION BY HAIRS

In other cases buds are protected by hairs. These fall into three main categories:

1. Hairs which form a felt or fur.
2. Stiff, bristly hairs.
3. Glands.

Many species are glabrous, or hairy, according to the conditions in which they live; for instance, there is a common English *Polygonum* which, from growing sometimes on land and sometimes in water, is known as *P. amphibium*. Land specimens are hairy, especially at the nodes, while specimens growing in water have no hairs.

It has been suggested that the hairs at the nodes prevent small climbing insects, such as ants, from reaching the flower, which they would rob of its honey without rendering any service in return in the way of cross-pollination. When growing in water the plant obviously needs no such protection.

Protection by Fur or Felt

Hairs forming a fur or felt may act in various ways; as, for instance:

1. By warding off excessive moisture.
2. By preventing too much transpiration.
3. By protecting the buds from excessive cold.

4. By making the buds unpalatable or inaccessible to insects.

5. By toning down the light.

In some cases, as in Mullein (*Verbascum*), the whole plant is covered with felted hairs.

In the Wayfaring Tree (*Viburnum Lantana*) (fig. 186, p. 118) the outer leaves of the bud protect the inner, but they all develop, and suffer very little from the cold, as they are protected by a thick coat of stellate hairs, which cross and intercross, thus forming a sort of grey felt. In the Dogwood (*Cornus sanguinea*), Buckthorn (*Rhamnus Frangula*), and others, the young leaves are similarly protected. In the Vine, again, the bud is covered only by a felt of hairs.

Lastly, in some plants, as in the Horse Chestnut (*Æsculus Hippocastanum*) and Plane (*Platanus*), some of the scales protecting the bud are hairy.

In the Plane (*Platanus*) the stipules are connate, the upper part being turned over in a sort of frill, so that they almost resemble a green flower, from the centre of which the stalk emerges (fig. 136). If the base of the leaf-stalk be examined, it will be found, as we have already seen, to form a regular cap, protecting the bud. After the leaves have fallen the winter-buds are covered by several cap-like stipules (see figs. 263–268), the leaves belonging to which have become completely aborted. The outer stipule or cap is brown or reddish brown, and secretes a gummy substance on its inner surface, besmearing the bud as in the Horse Chestnut, but only in the very early stages. As the bud swells the outer cap becomes ruptured, and appears then like a deeply concave scale, which is glabrous, or nearly so. This is followed by others, which attain a somewhat larger size before the expanding bud causes them to split; they are densely covered with brown hairs externally and glabrous internally.

In the Horse Chestnut the fur is on the young leaves themselves. In this species, as in many others, the hairs drop off when the leaf expands and their function is fulfilled.

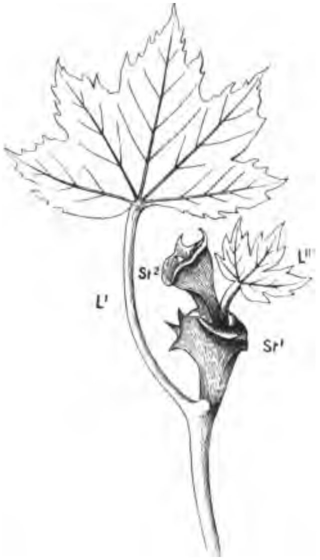


FIG. 136. — OPENING SHOOT OF PLANE. Two-thirds nat. size. L', L'', successive leaves with their stipules, St^1, St^2.

Virgilia lutea and *Gymnocladus*, both members of *Leguminosæ*, and *Pterocarya*, an ally of the Walnut, may be mentioned as other cases in which the bud is well protected by furry hairs.

Protection by Stiff Hairs

In many cases, as, for instance, in the common *Stachys* (*S. sylvatica*) (fig. 6, p. 5) and its allies, the bud is protected by stiff hairs.

In certain species such hairs contain an acrid liquid, as in the Common Nettle (*Urtica dioica*).

Protection by stiff hairs occurs also among the *Labiatæ* in *Galeopsis* (*G. Tetrahit* and *versicolor*); among the *Boragineæ* in *Echium*, *Lycopsis*, *Borago*, *Anchusa*; among the *Loaseæ* in *Loasa*; among the *Leguminosæ* in *Mucuna*; *Saxifrageæ* in *Davidsonia*; *Malpighiaceæ* in *Malpighia*, &c.

These hairs constitute, however, a protection to the plant as a whole, rather than to the buds specially.

Protection by Gum, Resin, or Turpentine

In other cases buds are protected by gummy or resinous secretions, as in the Horse Chestnut (*Æsculus*), the Poplar (*Populus*), Hazel Nut (*Corylus*), Honeysuckle (*Lonicera*), Currant (*Ribes*), Lilac (*Syringa*), Hornbeam (*Carpinus*), Elder (*Sambucus*), and Alder (*Alnus*), in many herbaceous plants (*Viola*, *Helianthus*, *Salvia*), and most Conifers.

The gum is often confined to the outer surface, the interspaces between the leaves being filled by hairs.

The gum or resin is secreted by hairs, by glands, by leaf-teeth, or by the general epidermis. The gum cells are generally developed early, and are short-lived. The secretion lessens transpiration, and in many cases also serves to protect the young leaves from insects and other animals. Smaller insects would get legs and wings clogged by the sticky secretion, and the scent or taste would act as a deterrent to browsing animals.

Glandular Hairs

Glandular hairs sometimes take the form of papillæ, and are in many species club-shaped, or resemble large-headed pins; they are often richly coloured, as, for instance, in some of the Currants, Geraniums, &c., glittering in sunlight like emeralds or rubies. They often develop very early, showing that they are intended to protect the young and tender leaves. In such cases they soon wither away; in others, however, they persist as long as the leaf, especially in hot and dry countries, which are particularly rich in aromatic plants.

Pleasant as is their smell—that, for instance, of the Lavender—such plants are too astringent to be eaten, and are thus protected from browsing quadrupeds.

The secretion may be either a gum, which, for instance, is richly secreted in the buds of some species of *Polygonum*; or a resin; or both may be present together. The resin, according to Hanstein (15), is generally secreted in the interior of the cells, and oozes through the cell wall, while the mucus is generally the product of the epidermis. The properties and functions of the two are no doubt different. Some plants secrete both, as, for instance, the Horse Chestnut.

The development of such glandular hairs in Lilac is shown in figs. 137–139. A cell raises itself somewhat above the general level of the leaf, and becomes cut off by a transverse wall (fig. 137, *a*, *b*; fig. 138, *a*). It then divides into two transversely, the upper cell forming the head of the pin (fig. 138, *b*), which may divide again by vertical and transverse walls (fig. 139).

As a general rule special hairs develop themselves into glands. In the Plane (figs. 140, 141), however, we find a remarkable combination of the two. The hairs branch, and one fork may remain a simple pointed hair, while another develops a gland.

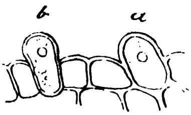


FIG. 137.

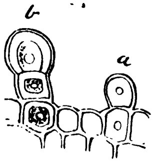


FIG. 138.

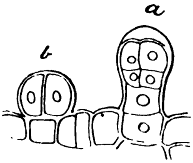


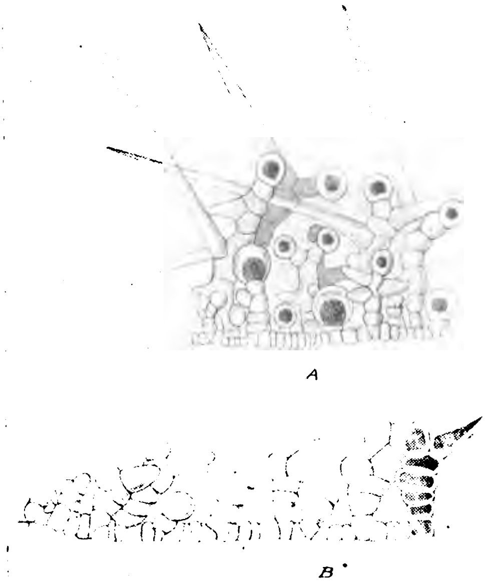
FIG. 139.

DEVELOPMENT OF STALKED GLANDULAR SECRETING HAIRS IN LILAC (*Syringa vulgaris*).
In fig. 139, *b*, the stalk has not been formed.

The glandular processes are sometimes highly developed; as, for instance, in the Rose and the Violet, where they are large and oval, one being formed at the tip of each tooth of the leaf.

In the Docks (*Rumex*), *Polygonum*, and Rhubarb (*Rheum*) the buds secrete a copious mucus, which in some of the larger species can even be squeezed out in a drop. It is formed by papillary outgrowths of the epidermis.

The buds of *Chilocarpus* look as if they were covered by red sealing-wax (16).



Figs. 140, 141.—Development of Hairs in Plane (*Platanus acerifolia*).

An epidermal cell divides into two unequal parts by an oblique wall. The upper grows out into a 2–4-celled hair, the apical cell of which becomes a spherical gland-cell; a lateral cell grows out obliquely into a long, pointed, hair-like structure. The lower figure shows the development, the upper the perfect form of the hairs.

The case of *Tabernæmontana* (1, 351) is especially interesting. The buds of this plant are covered with a gum which does not completely harden, but remains in a semi-fluid condition; and as the leaves previously covered up grow and expand, the gum remains attached to their edges, and stretches as a thin film between them. Thus the next youngest leaves are for a certain time enclosed in a small four-sided chamber, two opposide sides of which are formed by two leaves, and the other two opposite sides by a thin film of gum. The gum is eventually ruptured and the same process is repeated.

Glands are present in the axils of the leaves in the great majority of Crucifers (Norman says in nine-tenths), in most *Lythrarieæ*, and in many others.

The connection of these glands with the protection of the young and highly delicate leaf is further shown by their very early development. In fact, in some species there is a stage in which the glands are actually larger than the rudiment of the leaf itself. They are, however, often very transitory.

CHAPTER V

ON THE STRUCTURE OF BUDS

Having thus glanced at the various ways in which buds are protected by other and older structures, let us now see how they behave when they are, so to say, thrown on their own resources. In doing so I will, as far as possible, take in illustration our familiar forest trees and other common plants.

It is in some respects difficult to draw a hard-and-fast line between the buds now to be considered and those described in the last chapter.

In the Whitebeam (*Pyrus Aria*) (fig. 125, p. 82), for instance, the pedestal of the last leaf of the previous year is persistent, and, no doubt, of some use to the very young bud; but I class it here because in the main the shelter is due to the outer, modified stipules belonging to the bud itself.

It is remarkable how many devices Nature has adopted, and how much even nearly allied groups, such, for instance, as the Willows and Poplars, differ from one another.

It is, indeed, a very general, though not invariable, rule that the outer envelopes of winter-buds are formed of brown, more or less leathery scales; but as we shall see, these scales represent very different organs.

If we examine the bud of an Alder (*Alnus glutinosa*) (figs. 142, 143, 144) in winter, we shall find that it is

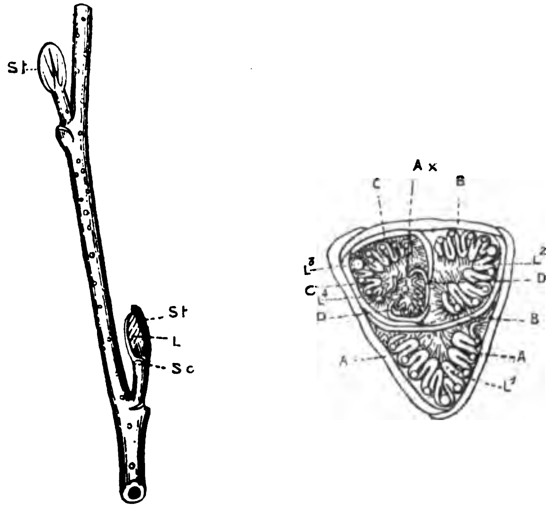


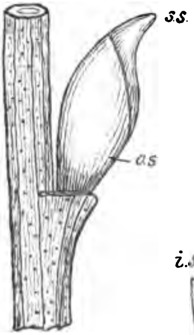
FIG. 142. FIG. 143.

BUD OF ALDER (*Alnus glutinosa*).

FIG. 142.—Portion of shoot, showing two lateral buds in winter; *Sc*, scar of fallen stipule, leaving L, the corresponding leaf, exposed; *St*, the stipule of the next leaf; the upper bud shows only one stipule, *St*, but none have fallen in this instance, which is the more common case. Nat. size.

FIG. 143.—Transverse section of bud in winter, × 6; A, A, first or outermost pair of stipules, belonging to the leaf immediately beneath them; B, B, second pair of stipules with their leaf; C, C, third pair; the fourth leaf, D, D, and stipules occupy the centre; *Ax*, axis.

protected by three, or sometimes four, purplish brown, leathery scales. The lateral buds sit on gradually elongating pedestals. If there are three scales, these are stipules. When four are present, one will be found to have at the end a few finger-like processes (fig. 142, L), the rudiment of a leaf-blade. At the base will be found the more or less evident scars left by the two stipules.



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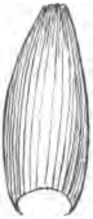

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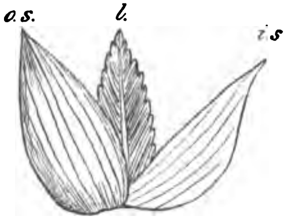

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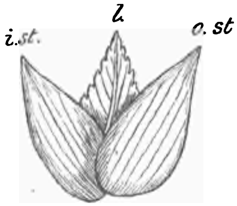

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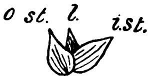

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ALNUS GLUTINOSA, × 3.

FIG. 144.—Portion of shoot bearing a lateral bud; *o.s.*, outer scale; *s.s.*, second scale—that is, the outer one of a pair of stipules.
FIG. 145.—Outer scale of winter-bud.
FIG. 146.—*o.s.*, outer, and *i.s.*, inner stipule of the first distinct pair; *l*, their leaf, flattened out like the stipules.
FIG. 147.—*o.st.*, outer, and *i.st.*, inner stipule of the second distinct pair; *l*, their leaf.
FIG. 148.—*o.st.*, outer, and *i.st.*, inner stipule of the third distinct pair; *l*, their leaf.

In this case, therefore, the last leaf of autumn is small, and sooner or later falls off; but, in connection with the stipules of the next leaf, it often assists in protecting the bud through the winter. It often, however, becomes detached, and in such buds as shown in the transverse section (fig. 143) the young leaf-blades are protected by three stipules, two belonging to the outer leaf, the third to that next following.

Here, therefore, though the main protection is afforded by stipules, the leaf-stalk and leaf-blade of an older leaf sometimes take a part in it.

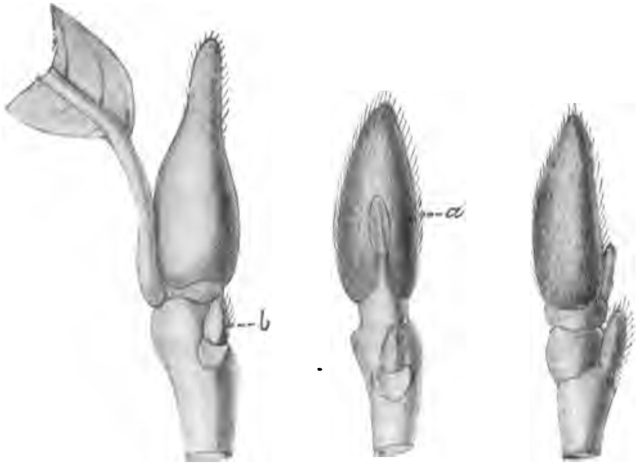


Fig. 149. Fig. 150. Fig. 151.

Magnolia Yulan, × 2.

Fig. 149.—Shows uppermost leaf with its stipules protecting the terminal bud in autumn; *b*, bud in the axil of the next lower leaf which has fallen.
Fig. 150.—Second stage, shows aborted leaf, *a*, the stipules of which protect the winter-bud.
Fig. 151.—Side view of same.

The second pair of stipules (fig. 147) of the more typical lateral buds are free, unequal, imbricate, and completely cover their own leaf and two out of the three sides of the more or less trigonous bud. The outer stipule of this second pair is ovate, more or less exposed along the middle and at the apex, which is curved, the exposed portions being more coriaceous than the rest. The inner of the two is half-ovate, pale green, and membranous. Both are traversed longitudinally by slender parallel nerves. The leaf in connection with the second pair is lanceolate-oblong, acute, serrate, glandular, and plicate along the course of the ascending nerves. It is more or less folded over the younger members of the bud. All the leaves and stipules are glued together by a viscid, resinous, fragrant gum, secreted by glands.

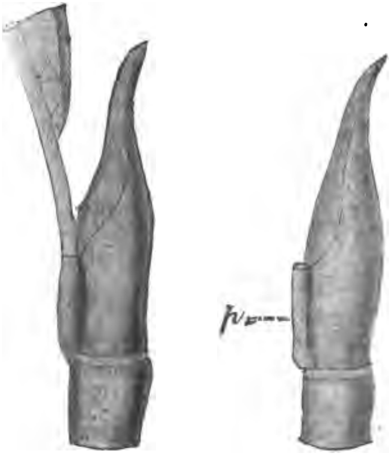


FIG. 152. FIG. 153.

TERMINAL BUD OF MAGNOLIA UMBRELLA, × 1¼.

FIG. 152.—Uppermost leaf still present.
FIG. 153.—Uppermost leaf has fallen, leaving only a pedestal, *p*; its stipules remain to protect the winter-bud.

The third pair of stipules (fig. 148) are slightly unequal, narrowly ovate or lanceolate, membranous, and more faintly nerved than the previous pair. The outer stipule envelops about two-thirds of the bud, including its fellow-stipule and the leaf. The latter is ovate-elliptic and folded over the younger members of the bud as a rule. The fourth pair of stipules and their leaf (fig. 148) are sometimes very similar to the preceding set, sometimes much smaller. This difference is apparently due to the relative vigour of the axis bearing them.

A somewhat similar case is afforded by certain species of *Magnolia*. In *Magnolia Yulan* the stipules of the uppermost leaf protect the young bud in autumn (fig. 149), but when it drops the stipules fall with it. This leaves a small undeveloped leaf-blade (fig. 150, *a*), which soon perishes. The stipules belonging to it, however, remain, and form a silky case, which protects the bud.

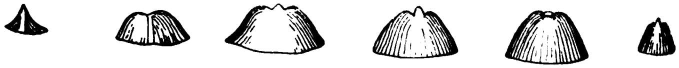
The leaf-blade corresponding to *a*, therefore, is useless and wasted.

Another species (*Magnolia Umbrella*) (figs. 152, 153) avoids this waste of power and material. When the last leaf of the year dies and drops off, the stipules belonging to it remain and protect the bud (fig. 153). Under these circumstances the leaf corresponding to *a*, which in *Magnolia Yulan* perishes uselessly, in *Magnolia Umbrella* is still retained, and develops into the first leaf of the following year. In *M. Soulangiana*, a garden hybrid, there is a similar arrangement.

PROTECTION BY THE LEAF-BASE

ROSE

The bud of the Rose in December (figs. 154–9) consists of a number of scales with three more or less well-marked projections at the apex. In this case the scale itself represents the leaf-base, while the stipules and upper part of the leaf are indicated by the three points. The outermost scale is the shortest, and they gradually



SCALES OF ROSE-BUD.
FIG. 154, first scale; FIG. 155, third do.; FIG. 156, fourth do.; FIG. 157, fifth do.; FIG. 158, sixth do.; FIG. 159, ninth do.

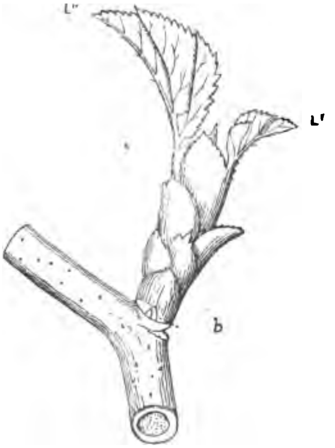


FIG. 160.—EXPANDING BUD OF ROSE.
Stem bearing expanding lateral bud, × 2; one scale has fallen, revealing its axillary bud (*b*); five scales are shown, and two of the first leaves. Sketched March 24.

increase in length. After about ten of such scales the little leaf-blade becomes much larger, and the leaf-base smaller, in proportion (see fig. 160).

PORTUGAL LAUREL (*Prunus lusitanica*)

The bud-scales of the Portugal Laurel are also leaf-bases. They are serially continuous with the leaves. The first scale covers less than half the bud and overlaps the second slightly at the base. It presents three points at the apex, or rather two points with a blunt process between them. These are the rudiments of the petiole and stipules. The second scale is longer, but otherwise not materially different. The third scale attains the full length of the bud, the petiole being more acuminate than in the previous scale, and longer than its stipules. The fourth scale is precisely similar, and covers more than half of the bud. All the stipules are ciliate and serrulate.

The fifth scale is shorter, and much more rounded at the base. It covers three-quarters of the bud or more. The sixth and seventh scales are smaller and shorter than the previous ones, and cover the bud, with the exception of a small slit at the base, where the edges of the stipules do not come in contact.

At the eighth node in the terminal bud examined the first true leaf occurred. It was small, subulate, slightly conduplicate, but colourless, and much shorter and narrower than its green and ciliate-serrulate stipules.

The ninth and tenth nodes bear leaves somewhat better developed, but their stipules are smaller and narrower. The fourth leaf, at the eleventh node of the bud, is conduplicate, and as long and about as wide as its stipules, without being unfolded. Succeeding leaves and stipules are very much smaller in the bud at this stage, but otherwise similar to the fourth.

It will be noted that the stipules become almost separate from their leaf from the first one onwards, even in the bud stage. The stipules are deciduous, falling before the end of the summer.

MAPLE (*Acer*)

In species which have no stipules there is nothing to distinguish the base of the leaf from the petiole.

Thus, if we look at the winter-bud of a Sycamore, a Maple (figs. 161, 162), or a Horse Chestnut, we find it covered by a number of brown, leathery scales, which are, like the leaves, opposite and decussate, so that one might at first sight be disposed to regard them as a simple form of leaf. On looking more closely, however, we shall soon find one which shows a scar or three small teeth at the summit. When the plant begins to grow in spring some of the scales, especially on certain trees, enlarge somewhat, and show small but often well-developed leaf-blades at their tip. In the Norway Maple (Pl. II. figs. 2–4) these scales enlarge and assume a beautiful red colour, so that the growing bud looks almost like an opening flower.

These bud-scales, therefore, are evidently the bases of leaf-stalks.

If, without waiting for the spring, we open a bud in summer, say in July, we shall find five or six pairs of scales, each pair at right angles with the preceding, and then a beautiful little crown of tender green leaves. Fig. 161 shows such a bud, drawn in December, after the removal of one of the last pair of scales. The remaining scale is shown forming a large hood over the little leaves, which at Christmas only occupy about half the space in the bud.

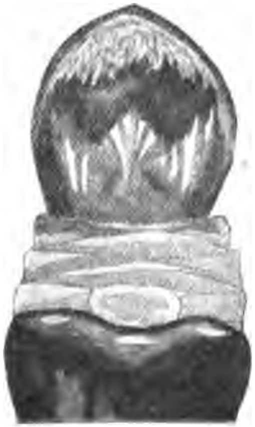


FIG. 161.

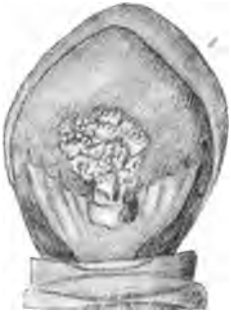


FIG. 162.

BUDS OF MAPLE.

FIG. 161.—Leaf-bud. FIG. 162.—Flower-bud.

Other buds (fig. 162) contain flowers. Both are lovely, and I do not know which is the more exquisite.

ASH (*Fraxinus*)

The buds of the Ash (*Fraxinus excelsior*) (figs. 163–5) are olive-green, so dark as to be almost black. Tennyson, in the 'Gardener's Daughter,' describes Juliet's hair as

> More black than ash-buds in the front of March.

The stems are much paler. The lateral buds are almost completely covered by the two outer scales. The scales of the terminal bud are often more or less bent. The scales are leaf-stalks, and generally show more or less rudimentary leaflets at the tip. The outer scales are

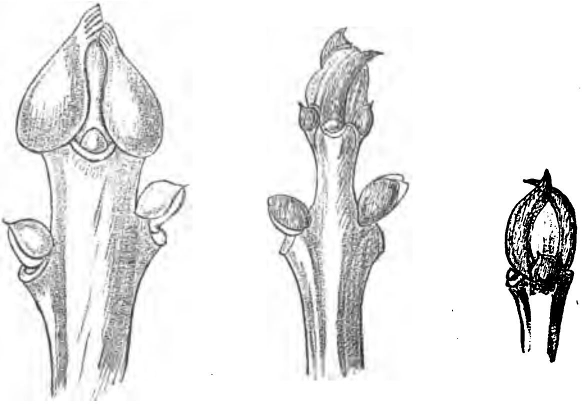


FIG. 163. FIG. 164. FIG. 165.

ASH BUDS. Nat. size.

In fig. 164 and fig. 165 successive pairs of scales have been removed from the terminal bud.

thick, and rather furry on the inner side. The second pair are furry on the outer side, and especially on the edges. The third pair still more so.

The outer scales are not dead, like those of so many trees, but increase more or less in size. The dark colour is due to a layer of black, more or less angular bodies, which are flattened hairs, containing a dark resinous secretion, and do not increase in size or number. As the scale grows they are, therefore, carried further and further apart, and occupying a smaller relative portion of the surface, the general colour becomes lighter and greener.

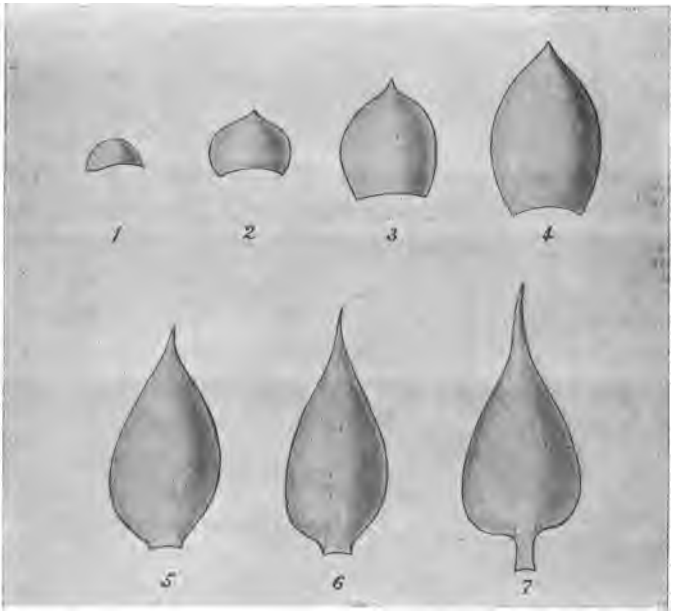
HORSE CHESTNUT (*Æsculus*)

The bud of the Horse Chestnut (*Æsculus Hippocastanum*) is protected by eight or ten scales. The outer ones are dark brown and short; they are serially continuous with the leaves of the preceding year. Those following become gradually longer and paler—often pinkish towards the end. The inner ones have a delicate fringe along their edges. The outside of the bud is very sticky. The scales are followed by normal leaves. Each segment of the leaf is conduplicate, and the midribs of the first, as well as the petiole and the internodes, are further protected by a thick felt, which is sometimes of a rich orange colour. This is less developed on the inner leaves, where it would not be so much wanted.

PROTECTION BY LEAF-BLADE

LILAC (*Syringa*)

The bud of a Lilac (*Syringa vulgaris*) at first sight closely resembles that of a Maple or Horse Chestnut, but the real structure is quite different. Each scale here represents a leaf-blade. The first pair (fig. 166) are short and broad; the second (fig. 167) are somewhat longer and pointed; the third



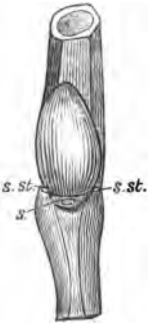
FIGS. 166–172.—LILAC, SHOWING SEPARATED BUD-SCALES. Enlarged.

(fig. 168) are longer than broad; the fourth (fig. 169) still longer, and rather narrowed at the base; the fifth (fig. 170) begin to assume the form of the leaf, and have a distinct, though very short, base; the sixth and seventh (figs. 171, 172) approximate still more to the final form of the leaf.

In the Holly also (*Ilex Aquifolium*) the bud-scales are leaf-blades.

THE WILLOW (*Salix*)

The winter-buds of the Goat Willow (*Salix Caprea*) are ovate, obtuse, tumid, relatively short, and more or less downy. The terminal bud dies, so that growth is renewed by the lateral ones. The bud is covered by a cap or scale in one piece, which shows no line of cohesion on either the anterior (fig. 173) or posterior face (fig. 174). Laterally, however, there are two strong ribs or keels, one on each edge. When growth recommences in spring the scale splits regularly from apex to base on the posterior face, and from the apex downwards, for one-third to one-half its length, on the anterior face (fig. 175). If the scale splits further, it does so irregularly. The whole scale, flattened out at fig. 176, shows the extent of the natural splitting, and also the two ribs or keels. This method of splitting and the two ribs indicate that the scale of the winter-bud is composed of two leaves, inserted right and left on the axis and cohering by their anterior and posterior edges. The first leaf-blade (fig. 177) is roundly ovate, obtuse, densely silky on the back and edges, and thinly hairy on the inner face. The second and third leaf-blades are oval-oblong, obtuse, and narrower. The fourth is oblong and more narrowed to the base. The fifth is lanceolate; and the sixth and seventh are very similar. The eighth leaf-blade is more decidedly narrowed to the base, and when *in situ* is more completely rolled round the bud than the previous ones, almost entirely covering it. It will be seen that there is little difference between the lengths of the first eight leaf-blades. The ninth, tenth, and eleventh leaves are very similar to the



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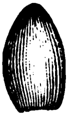

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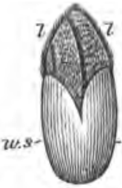

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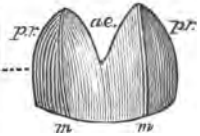

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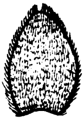

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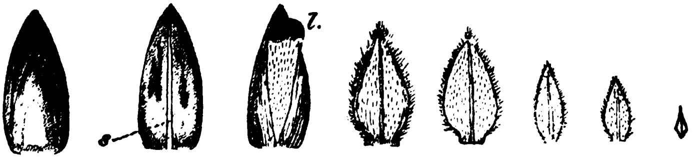
Salix Caprea.

Fig. 173.—Portion of shoot with a lateral bud; *s*, scar of fallen leaf; *s.st.*, scar of fallen stipule.
Fig. 174.—Posterior view of the same bud.
Fig. 175.—Anterior view of another bud bursting, showing the silky leaves, *l*, *l*; *w.s.*, winter-scale.
Fig. 176.—Another view of the same scale removed and spread out, showing two midribs, *m*, *m*; *a.e.*, anterior edges, slit naturally; *p.r.*, posterior edges, slit to the base naturally on the bursting of the bud.
Fig. 177.—The first leaf from the bud.

eighth, but much shorter and smaller. The stipules are large, particularly on the leafy shoots; but they develop after the leaves are expanded, or during that process. Some forms are exstipulate.

The winter-buds of the White Willow (*Salix alba*) are all axillary; the terminal one, as well as the tip of every shoot, dies. The buds are oblong, obtuse or subacute, compressed antero-posteriorly, but tumid on the anterior face (fig. 178), thickened at the edges, and have a thickened suture (fig. 179) along the middle of the posterior aspect. The cap-like scale seems to consist of two leaves united; its thickened edges and the strong, slightly branched nerve, easily seen on the inner face of these thickened edges, tend to support this view; but no suture is discernible on the anterior face. When growth recommences in spring, the scale bursts along the suture on the posterior face (fig. 180).



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SALIX ALBA.

FIG. 178.—Anterior aspect of winter-bud covered with one scale.
FIG. 179.—Posterior aspect of the same, showing the median thickened suture, *s*.
FIG. 180.—Scales of winter-buds bursting along the suture on the posterior aspect, showing the mass of leaves, *l*, bent at the apex.
FIG. 181.—First true leaf, immediately inside the winter-scale.
FIG. 182.—Second leaf. FIG. 183.—Fifth leaf. FIG. 184.—Eighth leaf.
FIG. 185.—Tenth leaf.

When the tip of the scale dies in winter, it breaks off during the bursting of the bud; and when the whole of it dies, the growing leaves rupture it at its insertion on the stem.

The first normal leaf-blade (fig. 181) is ovate, flattened on the posterior face against the axis, incurved at the sides, covering two-thirds of the bud. Both the dorsal and inner faces are silky; the edges are ciliate.

The second leaf-blade (fig. 182) is very similar.

The third is smaller, and covers about three-quarters of the bud, but otherwise is similar. The fourth is smaller, but covers about seven-eighths of the bud.

The fifth (fig. 183) is lanceolate and very much smaller, but otherwise similar to previous ones. The sixth leaf covers the bud, with the exception of a small slit at the base; but the seventh overlaps at its edges, completely enclosing the bud. The eighth leaf (fig. 184) is very small and membranous. The ninth leaf is membranous and almost glabrous; while the tenth (fig. 185) is lanceolate, acuminate, subtransparent, glabrous, and minute. All these smaller leaves are completely convolute, and they gradually open at the edges as the younger members of the bud become bulky.

The stipules are minute or undeveloped in the winter-buds. The convolute vernation of the leaves, and their silky, densely ciliate character amply protect the younger members. The bursting of the winter-scale along the posterior face allows it to prolong its period of protection.

I have been in some doubt with respect to the nature of the scale covering the winter-buds, but have come to the conclusion that this scale consists of two modified leaves, connate by their margins along the median line of the posterior and anterior aspect of the bud respectively. The following reasons seem to justify this view:

1. The scale in all the eleven species examined burst along the posterior face, generally to the base. *Salix pyrifolia* and *S. reticulata* are exceptions, inasmuch as they generally split at first a little more than halfway down. The swelling of the axis completes this operation later on.

2. There is sometimes a ridge on the posterior face corresponding to the line of union, as in *S. alba* and *S. cinerea.* In *S. cordata* there is a wide shallow groove at the same place.

3. The anterior face during the expansion of the buds in spring becomes emarginate, bidentate, or more or less deeply bifid at the upper end. *S. alba* and *S. lucida* are exceptions, inasmuch as the anterior face remains entire. I have observed no ridge, indicating union, on the anterior face; but as this is generally absent or inconspicuous on the posterior face, it does not much invalidate the presumed cohesion of the anterior edges of the leaves.

4. Another strong reason for regarding the outer sheath as representing a pair of leaves is that it is more or less carinate on the edges, right and left —that is, laterally. The inner face shows a number of longitudinal, parallel nerves, the two strongest of which occupy the position of the carina or keel, and correspond to the midribs of the two leaves. The midribs being right and left of the bud, agree with the insertion of the first two leaves of axillary buds, those leaves being generally at right angles to the leaf on the main axis.

A curious case occurs in *Salix cordata*, *S. lucida*, and *S. lanata*. The inner membranous face of the scale separates more or less completely from the coriaceous outer one, and resembles a second scale. It is, however, exactly opposite to the outer layer of the scale (not alternate), and is divided in the same way as the outer layer.

Perhaps, however, the strongest reason for regarding the outer sheath as composed of a pair of leaf-blades is that we often find a pair of buds at the base. Lindley [1] quotes this as showing that stipules occasionally develop buds at their base. It seems more reasonable to regard the fact as evidence that they represent leaves, and not merely stipules.

It is remarkable that while in the Poplars (*Populus*) the buds are protected by the stipules, in *Salix* the stipules are minute in the bud, or even absent, and this function is performed mainly by the leaves.

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[1] *Introd. to Botany*, p. 99.

The stipules, however, though always very small in bud, and in some species (*S. retusa*, *Grahami*, *Caprea*, *repens*, &c.) permanently so, in others become larger, and in some (*S. dasyclados*, *myricoides*, &c.) attain a considerable size. Their chief function appears to be to protect the axillary buds, which are also sheltered by the dilated and concave bases of the petioles. That the winter-buds of the Willow should be protected by modified leaves is the more remarkable since some species at least subsequently develop large stipules.

Ohlert (17) mentions the Willow among the cases in which there is no terminal bud. At any rate, it appears rarely, if ever, to maintain itself permanently. But, although as a rule it soon perishes, it is formed on the same plan as the lateral buds.

VIBURNUM (THE GUELDER ROSE)

The winter-buds of the Guelder Rose (*Viburnum Opulus*), both terminal and lateral (Pl. II. fig. 1), are oblong-oval, varying considerably in size, according to their situation on the shoots and the strength of the latter. Each bud is covered by two pairs of scales, which are modified petioles bearing just a trace of an undeveloped lamina at the apex.

The outer pair of scales are the most modified and cohere by their edges; they are inserted right and left of the axis, and likewise of the leaf in whose axil they occur. They are brownish red, glabrous, shining, and for a time increase in size with the swelling of the buds in spring. Finally, they burst antero-posteriorly along the line of union for a quarter to three-quarters of their length, the greatest amount of fission occurring, as a rule, along the posterior face, allowing the developing axis with its leaves to make its exit at the apex. Each of these scales is keeled, the keel corresponding to the midrib. Three or five veins may be seen on the inner face, corresponding to the principal vascular bundles running through the petiole into the lobes of the lamina. Three of them generally terminate in gland-like tips.

The second pair of scales are more membranous, pale green, five-nerved, reticulate, cohering in a tube, which bursts from the apex downwards for one-third to one-half its length, or more, when growth is resumed in spring. They double their length during and after the expansion of the buds, and are, therefore, intermediate in character between the most modified pair of scales and the true leaves. The three principal veins terminate in gland-like teeth, thus, possibly, indicating the presence of the lamina in an undeveloped state. When fully developed they are seen to be spathulate by a dilatation of the upper half.

If the terminal bud is examined, it will be seen that the scales are opposite decussate, and serially continuous with the uppermost pair of leaves that fell in the previous autumn. The young leaves in spring are serially continuous with both the two pairs of scales

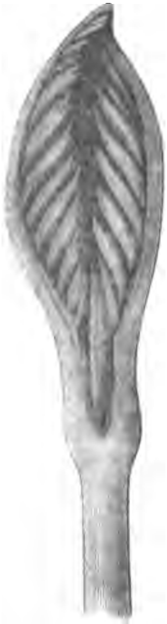


FIG. 186. – VIBURNUM LANTANA, × 2.

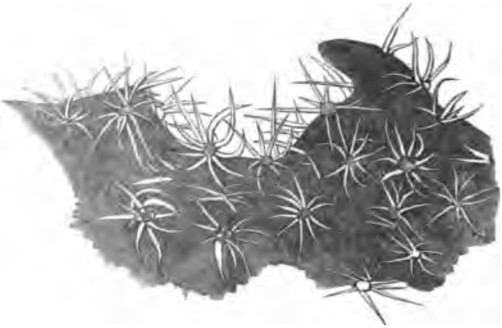


FIG. 187.—PART OF LEAF OF V. LANTANA, × 75, showing stellate hairs.

and the leaves of the previous season. Unless the terminal bud ends in an inflorescence, the shoots of successive years are interrupted only by two pairs of scales. Strong shoots do, as a rule, terminate in an inflorescence, and the apex dies, so that growth is resumed by the lateral buds.

In the flowering buds the second pair of scales are larger, vase-shaped, and also more deeply divided, especially on one side. Those which bear leaves only are flattened at right angles to the stem.

In *Viburnum Lantana* (Wayfaring Tree) (figs. 186 and 187), on the contrary, the leaves are all normal. The outer ones protect the inner; but they all develop, and suffer very little from the cold. They are protected by a thick coat of stellate hairs, which cross and intercross, thus forming a sort of grey felt. As the young leaves increase in size these hairs do not appear to increase in number, and they are, consequently, carried further from one another. Fig. 187 is taken from such a bud which had attained a length of rather more than an inch.

Protection by Leaf-stalk

In the Elder (*Sambucus nigra*) the scales protecting the bud are petioles. Externally are a pair of very small brown scales; then a larger pair at right angles; then a pair much more elongated, greenish, and with more or less developed leaves. In this respect they differ very much; sometimes there are three small points at the summit, sometimes a well-formed leaf; and every gradation between the two occurs. The two opposite leaves often differ considerably, and when one of the two has its back to the main stem it is often much smaller than the outer one.

PROTECTION BY STIPULES

In by far the larger number of cases stipules protect the younger leaves only, but in some species they develop early, and cover their own leaf-blades.

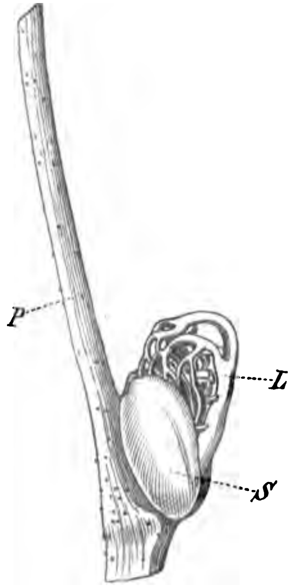


FIG. 188.—SHOOT OF LEEA COCCINEA.
P, petiole of leaf, the lamina being cut off; *S*, stipule; *L*, young leaf emerging from stipules.

This is the case, for instance, in the Pea (fig. 26, p. 23) and the Hop (*Humulus Lupulus*) (figs. 47, 48, p. 34).

In the Vine, again, the stipules are large, and appear some time before the leaves, covering the whole bud (figs. 127, 128, p. 84). They fall early.

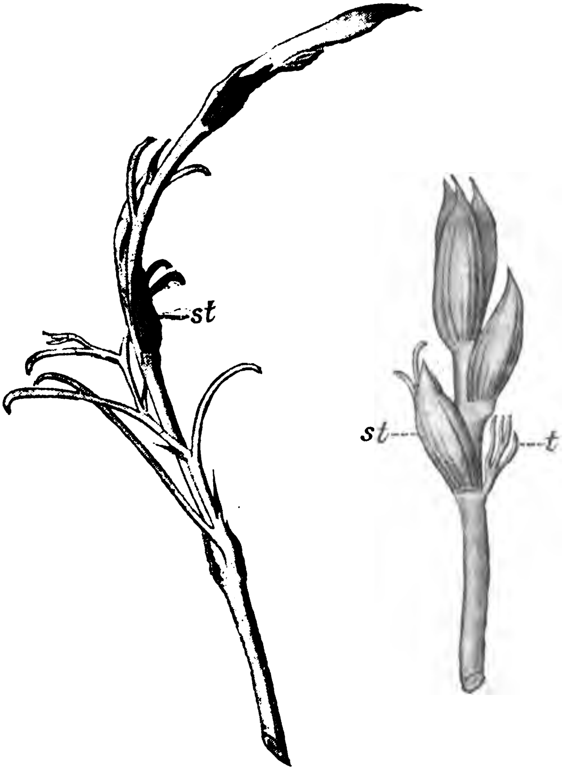


Fig. 189.—Virginian Creeper.
St, stipule; *t*, tendril.

In *Leea* (*L. coccinea*), another member ot the Vine family, the same thing occurs; they are also (fig. 188) large, and enclose the whole bud, but they are persistent.

In the allied genera, *Cissus*, and *Ampelopsis* (Virginian Creeper) (fig. 189), the stipules also cover their own leaf-blades.

In *Bucklandia populnea* (fig. 190), a Himalayan plant which belongs to the *Hamamelideæ* (the Witch Hazel family), the stipules are large, oval, unequal-sided, and cohere at the edges, thus forming an almond-shaped box, within which the leaf is developed. The petiole elon-

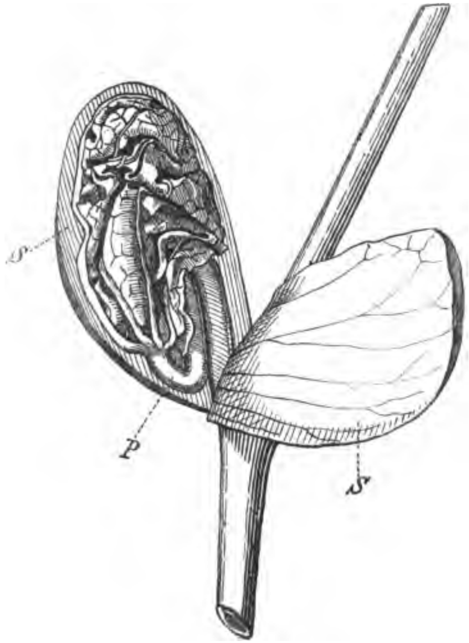


FIG. 190.—SHOOT OF BUCKLANDIA POPULNEA.
S, *S*, stipules ; *P*, petiole.

gates greatly, and becomes twice bent, as shown in the figure, so that the leaf remains erect. This arrangement is, so far as I know, unique.

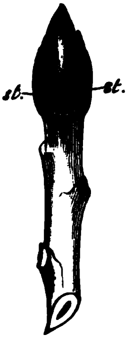
In the Passion Flower (*Passiflora racemosa*) the stipules are large, foliaceous, and developed far in advance of their own leaves, so that each pair enclose their own leaf, the simple tendril in its axil, and the younger portion of the bud. Proceeding from the outside inwards, the stipules change considerably, being first ovate, gradually becoming smaller, then lanceolate, and finally subulate. In some other species of *Passiflora* the stipules more or less completely protect the bud, and the petioles are terete, and are provided with glands.

In by far the greater number of cases, however, stipules protect the younger leaves only.

In the Willows, as we have already seen, the stipules develop late, and the bud is protected by a pair of modified leaves. In the allied genus, *Populus* (the Poplar), on the contrary, the stipules develop early, and to them the protection of the bud is entrusted.

In the Black Poplar (*Populus nigra*) the terminal bud (fig. 191) is conical and somewhat angular.

The first and second pairs of scales (fig. 192), forming part of the terminal bud, are stipules belonging to leaves that developed during the previous summer and fell in autumn. They only cover, however, a part of the bud. They are the hardest of the



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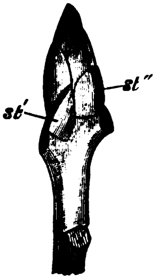

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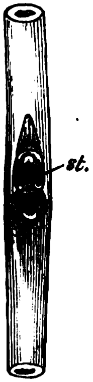

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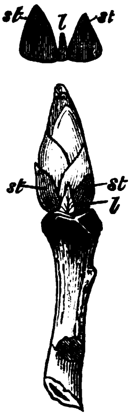

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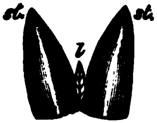

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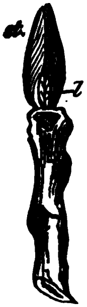

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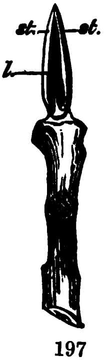

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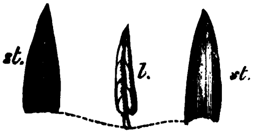


198

POPULUS NIGRA, VAR. PYRAMIDALIS, × 2. WINTER-BUDS.

FIG. 191.—Terminal bud showing one pair of persistent stipules, *st*, *st*, belonging to a leaf of a previous season.
FIG. 192.—Terminal bud showing one from each of two pairs of persistent stipules, *st′*, *st″*.
FIG. 193.—Axillary bud showing only one of the outer pair of stipules, *st*.
FIG. 194.—*l*, third leaf in the bud, often dying in winter; *st*, *st*, its stipules shown separately above.
FIG. 195.—*l*, fifth leaf in the bud; *st*, *st*, its stipules.
FIG. 196.—The same shown separately.
FIG. 197.—*l*, eighth leaf in the bud; *st*, *st*, its stipules.
FIG. 198.—*l*, outer face of eighth leaf; *st*, *st*, its stipules spread out.

stipules, because they are dead. The third pair are larger, and to them belongs the first leaf of the bud (fig. 194). The fourth pair are longer than the third. Their leaf-blade is subulate, and about one-third as long as their stipules. Sometimes it dies in winter. The fifth pair are sometimes nearly as long as the bud. The third leaf-blade belongs to them, and is considerably larger, though but slightly longer. The fourth leaf-blade is nearly as long as its stipules. The seventh pair are about half the length of their leaf-blade, and thin. The ninth and tenth pairs are less than half the length of their leaf-blade.

This represents the average composition of a bud at midwinter; but there is considerable variation in the relative lengths of the leaves and their stipules. Sometimes the third leaf belonging to the fifth pair of stipules is nearly equal in length to the latter, but it may be the fourth, fifth, or sixth leaf which attains this size. The first two or three leaves never attain any great size, even if they live through the winter. Their stipules, however, are always largely developed, and more or less cemented together with a viscid gum, obviously for the protection of the leaves. The leaves that attain a large size in the bud retain their predominance after expansion, while the small outer ones remain relatively small.

The axillary buds are smaller and somewhat differently constructed. The outer covering is short, broad, and open on the side towards the stem; the second is longer, and narrower in proportion.

Several of the species secrete a gum, which forms an additional protection to the bud.

THE LIME (*Tilia*)

In the Lime (*Tilia vulgaris*) (Pl. I. fig. 1) the pseudo-terminal and lateral buds are very similar. They are generally lop-sided or tumid on one side, owing to the thickening of the small outer scale, particularly along the midrib. The true apex of the shoot becomes disarticulated and falls off. The bud does not lie opposite the centre of the leaf, but a little on one side. As already mentioned (*ante*, p. 9), this occurs in other trees, as, for instance, in the Beech and Hornbeam (fig. 11). The consequence is that the pseudo-terminal bud has a scar on each side of it—one that of its leaf, the other that of the fallen shoot.

The scales of the winter-bud are arranged on alternate sides of the bud, the leaves being alternate and distichous. The outer scale overlaps the second at the base, but is little more than half its size, though two-thirds the length of the bud. The first two are coriaceous, glabrous, and not accompanied by a leaf; they are also obtusely and slightly carinate. Sometimes one stipule of the outer pair is absent.

The next two are larger, more nearly equal in size, roundly cordate, showing an inclination to become petiolate owing to their being much wider than their insertion. They are glabrous, as long as the bud, rolled round three-fourths of it, the outer one covering the same extent as the inner, which is more membranous, except at the tip. They are accompanied by a small, conduplicate, silky leaf.

The next pair are broadly elliptic, unequal, membranous, and more or less silky on both surfaces. The larger scale or stipule is always the outer of the pair. The second leaf is much larger than the first, densely silky, with unequal parts, the narrower one being uppermost. The edges of the leaf are always directed under the larger stipule; and it will be noted that the direction of the leaf and the larger of each pair of stipules are altered in each succeeding set. This is due to the alternate and distichous arrangement of the leaves.

The fourth pair are oblong-elliptic, covering three-fourths of the bud, as in succeeding cases, and more silky than the previous pair on the outer face, but otherwise similar. The leaf is as long as the next younger pair of stipules, and lies in a convex manner over them.

The fifth pair are oblong, and the outer stipule covers less than half of its fellow. The sixth pair are more unequal and very much smaller. The seventh pair are oblong-lanceolate and very small; while the eighth pair are still smaller and membranous.

The next younger leaf in each case lies beneath its own stipules, and in that position corresponds to the opening left uncovered by the previous and older pair. None of the pairs of stipules completely surround the bud.

The outer scales are often of a rich crimson (Pl. I. figs. 1, 2), and the next few sometimes of a brilliant ruby with greenish tips. When the buds first open the leaves, as is the case in other trees—for instance, the Beech, Hornbeam, Elm, &c.—turn downwards, assuming, as Mr. Henslow has pointed out, the attitude of some leaves when asleep, and probably for the same reason, namely, to expose a less surface to the sky during the cold nights of spring.

THE BIRCH (*Betula alba*)

In the Birch also the terminal shoot perishes, and the apparently terminal bud is really axillary.

If an apparently terminal bud is carefully examined in winter it shows four scars at the base. Two of these are large, and are those left by the death of the terminal shoot and the leaf respectively. The two smaller ones, which are not always easy to see, are those of the stipules of the fallen leaf.

The bud itself is ovoid-oblong, obtuse, glabrous, or with a few cilia at the margins of the scales, and deep brown. The outer scales represent stipules the leaf-blades of which are not developed.

The first pair are slightly unequal in length, and do not overlap at any point nor surround the whole of the bud. The second pair, when spread out, are almost semi-orbicular, rounded at the apex, and slightly unequal in length, the inner one being the longer and overlapped at the base by its fellow at both edges. They cover a considerable portion of the bud, owing to their width. The third pair are as long as the bud, covering the whole of the younger members and overlapping at their edges. They are more membranous than either of the one or two preceding pairs, and are more or less covered with a viscid gum. They are also slightly narrowed at the base. The fourth pair are more decidedly boat-shaped than the previous one, but are still imbricate. The first leaf generally occurs in connection with the third or fourth pair of stipules, but inside of, and covered by, them. It is rhomboid, acute, shortly petiolate, serrate, thinly pubescent, glandular, viscid, and concave. The fifth pair are somewhat smaller than the fourth, but otherwise similar, as is their leaf. The latter is much more involute in bud, though neither strictly convolute nor conduplicate. Its form is doubtless due to the abrupt arrest of the younger members of the bud; for the fourth and fifth pairs of stipules, together with the first and second leaf belonging to them respectively, are greatly in advance of those that follow. The sixth pair of stipules and the younger members of the bud they enclose will show a reason for the second leaf being partly involute, so as to occupy the space.

According to Henry (18, 309), the outer scales are the stipules of the last leaves of the previous year. The description given above, however, is, I believe, the correct one.

THE BEECH (*Fagus sylvatica*)

The bud of the Beech (figs. 199–210) is more complicated. It is elongated, spindle-shaped, half to three-quarters of an inch in length; on the outside are four closely imbricating rows of stipules, arranged apparently in opposite decussate pairs. I say apparently, because, as the leaves are alternate, it is possible that each pair of these stipules are really alternate, though so compressed as to appear to be opposite.

The first pair (fig. 200) are small, triangular, and pointed. The five following are also triangular, each rather larger than the preceding and more convolute, till they almost enclose the upper part of the bud. The lower ones are brown and coriaceous; the upper membranous, and furnished with numerous straight, longitudinal, parallel, slender veins running from the base to the apex. The covered parts are white, the exposed brown. The upper ones are fringed with long,

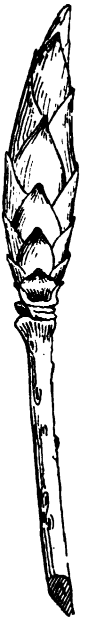


FIG. 199.

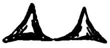


FIG. 200.

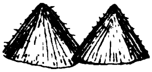


FIG. 201.

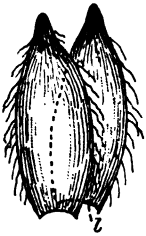


FIG. 202.

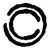


FIG. 203.

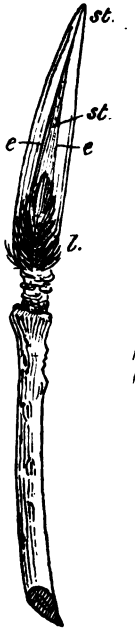


FIG. 204.

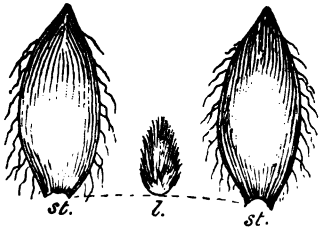


FIG. 205.

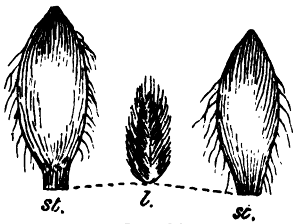


FIG. 206.

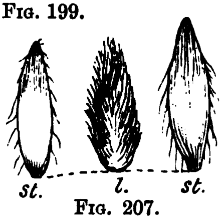


FIG. 207.

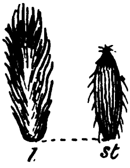


FIG. 208.

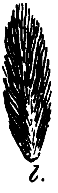


FIG. 209.

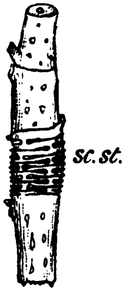


FIG. 210.

THE BEECH (*Fagus sylvatica*).

FIG. 199.—Winter-bud. FIG. 200.—First or lowest pair of stipules.

FIG. 201.—Sixth pair of stipules overlapping at the corners. FIG. 202.—Eleventh pair of stipules, showing how one is rolled within the other; *l*, position where the leaf should be, though it is yet absent. FIG. 203.—Diagrammatic transverse section of the stipules, showing the extent to which they overlap.

FIG. 204.—The bud after eleven pairs of stipules have been removed; *l*, the first leaf; *st*, *st*, the twelfth pair of stipules; *e*, *e*, the edges of the outer one of the twelfth pair. FIG. 205.—*st*, *st*, the twelfth pair of stipules flattened out; *l*, the first leaf belonging to the same. FIG. 206.—*st*, *st*, the thirteenth pair of stipules; *l*, the second leaf. FIG. 207.—*st*, *st*, the fourteenth pair of stipules; *l*, the third leaf. FIG. 208.—*st*, the only stipule of the fifteenth pair discernible in this bud; *l*, the fourth leaf. FIG. 209.—No stipule discernible in the bud examined; *l*, the fifth and last leaf discernible, occupying the centre of the bud.

FIG. 210.—Junction of the wood of two seasons' growth; *sc.st*, scars of the outer eleven pairs of stipules that covered the winter-bud and which were unaccompanied by leaves.

recurved, silvery or satiny hairs. They are sometimes a brilliant pink or rose colour after expansion, but less often than those of the Hornbeam. The fifth and sixth pairs (fig. 201) are ciliate with short hairs, and rolled round a considerable part of the bud.

The seventh pair are half as long as the bud, but otherwise like the sixth; the eighth pair, two-thirds as long as the bud; the ninth, nearly as long as the bud, with silky hairs directed downwards, and the outer one of the two distinctly overlaps the inner. The tenth pair are as long as the bud, and each is convolute, so as to cover nine-tenths of the bud, or even more. The eleventh pair (fig. 202) are similar, and almost meet at their edges. These eleven pairs of stipules show no traces of a leaf.

Fig. 204 represents a bud after the removal of the first eleven pairs of stipules.

About the twelfth pair there is a material change; they (fig. 205) are smaller, and between them is a leaf-blade; this is about one-third as long as its stipules, concave on the inner face, and plicate along the course of the ascending lateral nerves. The thirteenth pair of stipules (fig. 206) are rather narrower, especially at the base. The leaf is about half as long as the stipules. The fourteenth pair (fig. 207) are much smaller, thinner, narrower, and unequal, the inner one being the smaller. The leaf is three-fourths as long as its stipules. The leaf (fig. 208) belonging to the fifteenth pair is longer and more bulky than the stipule. The next leaf (fig. 209) is large, deeply concave, or rolled into a cylinder, occupying the centre of the bud, and densely covered with silky hairs on both surfaces, but particularly on the back, as are all the others.

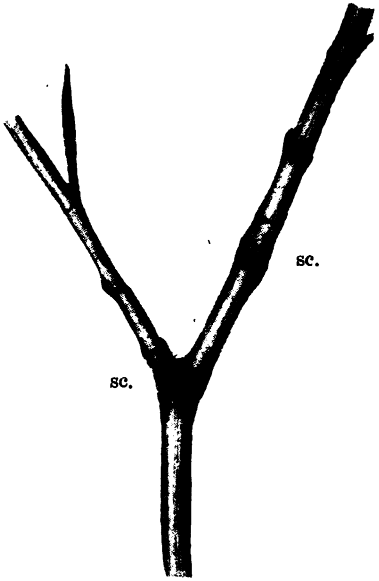


FIG. 211.—TWIG OF BEECH.
sc, *sc*, stipular scars at junction of wood of two seasons' growth.

The above description may be regarded as giving the average composition of the winter or resting bud of the Beech. Larger buds have a greater number of leaves and stipules; smaller buds, fewer. Strong shoots on vigorous young trees have more leaves, though the inner ones are very small or but slightly developed in winter.

If the branch is examined, the scars where the stipules were inserted may be seen, forming rings (figs. 210, 211) round the base of each annual shoot. The shoot elongates considerably between the leaves, but not between the stipules, so that the stipular rings remain close together; these are very persistent, and can be traced for twenty-five years or more.

The long, narrow, brown stipules of the bud are thrown off when the leaves expand, and may be found in large numbers under the trees. The terminal bud is straight; the lower ones stand out from and curve towards the twig. Before unfolding they tend to turn upwards, but afterwards bend down (Pl. IV. figs. 1–4), as in the Elm, &c. The leaves are plicate.

The flowering-buds (Pl. IV. fig. 7) are much thicker than the others.

THE HORNBEAM (*Carpinus Betulus*)

The bud of the Hornbeam (*Carpinus Betulus*) (Pl. I. figs. 4, 5) has at the base about half-a-dozen very small, dark scales; then two, pale at the base and brown above, rounded at the apex, and sometimes with two points; then two or three coloured like the preceding, but pointed; then follow the pair enclosing the first leaf. After these the stipules become longer, more hairy, and more rounded at the end; the brown part becomes shorter, and after one or two days disappears altogether; they are fringed with hairs. As the stipules expand the shoot turns down, so that the leaves hang towards the ground. The stipules are often a rich purple.

THE HAZEL NUT (*Corylus Avellana*)

The bud of the Hazel Nut (*Corylus Avellana*) (fig. 212) is protected by stipules which gradually increase in size. The first four pairs are without leaves. The fifth have a well-formed leaf. The second pair and following stipules are fringed with fine hairs round the edge. The stem and petioles have two kinds of hairs: 1, fine, silky, white and more or less adpressed; and, 2, reddish, upright, glandular hairs. The young shoot bends over downwards for protection from cold. The leaves are conduplicate. The stipules are often beautifully pink.

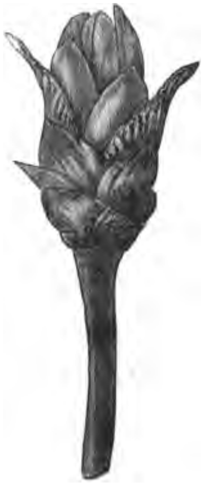
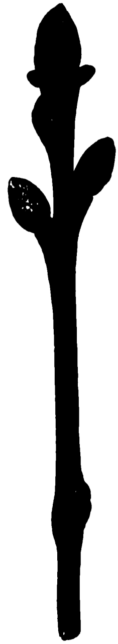


FIG. 212.— OPENING BUD OF HAZEL (*Corylus Avellana*), × 2.

THE OAK (*Quercus*)

The buds of the Oak (*Quercus pedunculata*) (figs. 213 and 214) are even more complicated than those already described; they are a rich brown, and make a beautiful contrast with the greyish black of the stems. They are short and conical, and the colour, together with the arrangement of the scales, gives them a curious similarity to a miniature cone of a Pine.



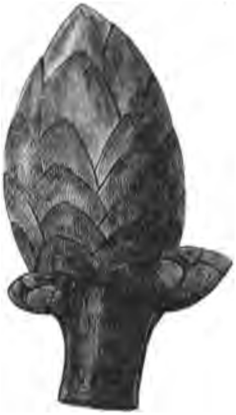
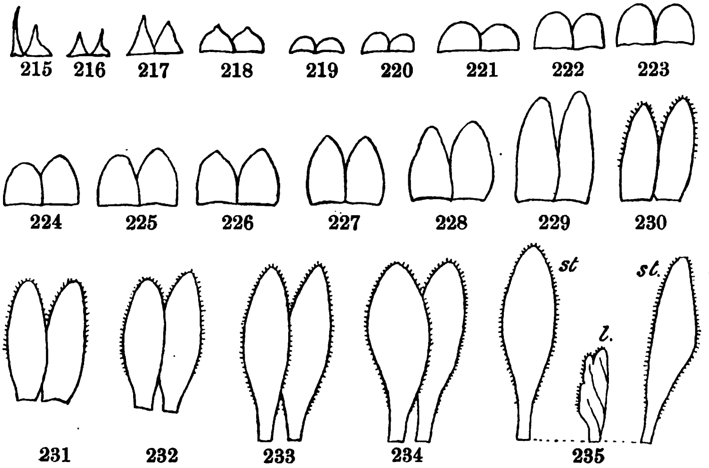


Fig. 213.—Oak Buds, Nat. size. Fig. 214.—Oak Bud, × 6.

The buds differ considerably in size, but are comparatively short, broadest above the base but somewhat below the middle, covered with dry brown stipules, arranged in five imbricating rows. The buds are slightly pentangular, each of the five angles being made up of one stipule from each of two contiguous and successive pairs. The pentangular character of the bud is due to the leaves being on the $\frac{2}{5}$ plan of arrangement. The centres of the stipules correspond with the angles, while the leaves lie in the middle of the flat surfaces.



QUERCUS PEDUNCULATA.

FIGS. 215–234.—Pairs of stipules forming the scales of the winter-bud, sketched in the first week of May; some of them had small lateral buds between them, but no leaf; the bud had resumed growth, was oblong, and 16·5 mm. in length; ×2.
FIG. 235.—×2. *st, st*, stipules; *l*, leaf, conduplicate in bud, but not likely to attain any great size if it had been allowed to develop.
FIGS. 229–235.—Stipules which had elongated when growth was resumed in spring.
N.B.—The bud sketched was a large lateral one, and the leaves would be aggregated at the apex of the shoot when the latter is full-grown.

The first two pairs (figs. 215, 216) have a slender point, which is often broken off in winter. The next two are also pointed; the next few are rounded and short; those following more and more elongated, and ovate, membranous, except at the base, becoming strongly ciliate or hairy at the margins, and densely hairy at the base on the inner face. The number of leafless stipules differs in different buds, but there are sometimes more than forty, or twenty pairs, before those containing the first leaf. Figs. 215–235 represent the series in a single bud. The first leaves are small, and often bent and crumpled from not having room to extend either longitudinally or laterally. They are obovate, very shortly petiolate, with two and three or three and four lateral lobes and a terminal one, greenish yellow and glabrous, with the exception of a few hairs on the midrib, especially on the under-side, with a few small hairs at the edges of the lobes beneath. They are accommodated in the middle line between the angles formed by the stipules and by the thinning away of the edges of the latter; and the lobes seem to favour their being crumpled laterally or pressed together at the sides, as they have not room to develop in a straight line.

The hairs at the edges of the stipules serve to keep the buds compact, and to drain away moisture down the outside. The hairs at their base internally fill up the space where the leaves become narrowed towards the petiole, and would also serve to keep the young and tender leaves warm.

Lateral and secondary buds occur frequently in the lower part of the primary bud, in positions corresponding to the axils of primary but aborted leaves. They have the same structure as the primary ones, but are much simpler, and consist of a few pairs of stipules, the outer ones of which are comparatively large. These buds appear but seldom or ever to become developed into branches on the expansion of the primary bud, but remain small. Accidents to the primary bud, however, would, of course, cause them to develop.

The following is the composition of a flower-bud—that is, one containing catkins:

The first fourteen pairs of stipules, or thereabouts, have neither leaves nor catkins, so that they merely serve the purpose of protection.

The first five pairs of stipules are very small and rounded; the first pair are often acuminate or tailed.

The sixth and seventh pairs are twice as large, roundly triangular, concave, and finely ciliate.

The eighth and ninth pairs are half the length of the bud, triangular, and obtuse.

The tenth pair are three-quarters the length of the bud, broadly triangular, subacute, covering a great part of the bud, and pubescent on the back.

The eleventh and twelfth pairs are as long as the bud, covering three-fifths of it, each stipule covering two faces of it, and the half of one stipule overlapping half of the other. The cilia are much longer than those of the previous stipules.

The thirteenth and fourteenth pairs are pubescent on both faces.

The fifteenth and sixteenth pairs cover a small, subcompressed, hairy catkin of male flowers. The catkin is axillary, but no leaf is discernible.

The seventeenth, eighteenth, and nineteenth pairs are much smaller than the two previous pairs, but otherwise similar, and each pair protect a catkin.

The twentieth pair are small, membranous, silky on both faces, covering a male catkin; and the twenty-first pair cover what appears to be a female inflorescence in a very minute or early stage of development. In all these cases leaves are entirely absent or indiscernible during the months of winter.

In the Evergreen Oak the leafless scales are comparatively few. As the tree belongs to milder climates, the leaves do not require so much protection.

Henry (18, 338) was of opinion that the outer scales consist of a leaf-blade connate with two stipules. The series given above in figs. 215–235 seems to me conclusive against this view.

WHITEBEAM (*Pyrus Aria*)

The scales of the winter-bud (fig. 236) of the Whitebeam (*Pyrus Aria*) consist of the base of the leaf—that is, the petiole in combination with the

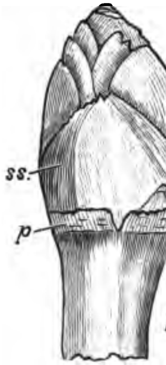


FIG. 236.

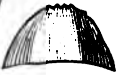


FIG. 237.

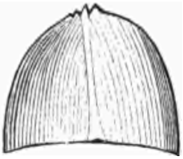


FIG. 238.

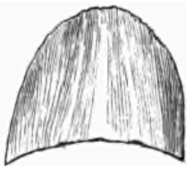


FIG. 239.

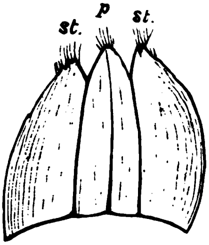


FIG. 240.

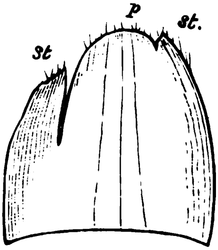


FIG. 241.

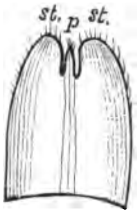


FIG. 242.

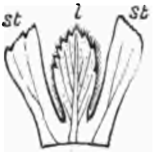


FIG. 243.

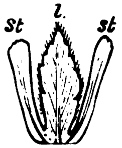


FIG. 244.

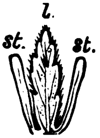


FIG. 245.

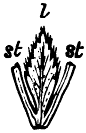


FIG. 246.

WHITEBEAM (*Pyrus Aria*).

FIG. 236.—Winter-bud; *p*, *p*, persistent base of fallen petioles; *ab*, axillary bud; *ss*, second scale. FIG. 237.—First scale. FIG. 238.—Second scale. FIG. 239.—Third scale. FIG. 240.—Fifth scale. FIG. 241.—Seventh scale. FIG. 242.—Ninth scale—showing stipules, *st*, *st*, and petiole, *p*. FIG. 243.—*l*, first leaf; *st*, *st*, its stipules. FIG. 244.—Second ditto. FIG. 245.—Third ditto. FIG. 246.—Fourth ditto.

stipules; and in this respect they closely resemble those of the Elm. At the base of the bud the persistent base of one or two leaves, that fell in autumn, may be found sheltering, it may be, axillary buds. These can easily be recognised by the scars of the three vessels (fig. 236). One obvious difference between the buds of the Whitebeam and the Elm is that the scales of the former are arranged in five ranks, while those of the latter are in two ranks, the difference being dependent upon the phyllotaxy.

The first scale (fig. 237) is semicircular and slightly erose at the apex, but otherwise entire. The second (fig. 238) is several times as large, and obtusely carinate. The third scale (fig. 239) shows three ribs or nerves, and is about as long as the bud before growth is resumed in spring. The fourth is similar. The fifth scale (fig. 240) of a good-sized terminal bud (from which the sketches were made) was 3-ribbed, more membranous, greenish and trifid at the apex, thus disclosing the true nature of the scales, namely, a combination of the base of the petiole and the stipules. All the scales are rather firmly glued together by means of a viscid gum secreted from a cluster of orange-coloured glands situated close to the base on the inner face. The sixth is similar.

The seventh scale (fig. 241) is still more membranous, more faintly 3-nerved, very unequally trifid, and enclosing three-quarters of the bud. The eighth is tridentate, and shows a transition towards the true nature of its component parts.

The ninth scale (fig. 242) is oblong, much narrower, and trifid. The middle tooth is subulate-terete, subfleshy, and red, being more like a petiole than in any previous scale. The three nerves are now closer together and directed into the petiole. The side lobes or stipules are rounded. The fifth to the ninth scale inclusive are more or less woolly on the inner face.

At the tenth node a normal leaf occurs (fig. 243). It is oblong-obovate, plicate, with ascending nerves, serrate, woolly, and slightly shorter than its oblong or spathulate membranous stipules, which show one or two nerves.

The leaf-blade (fig. 244) at the eleventh node is lanceolate, and slightly longer than its linear, 1-nerved stipules. The third leaf-blade (fig. 245) at the twelfth node is shorter and narrower, as are its stipules. The fourth leaf (fig. 246) at the thirteenth node is smaller, and shows a slight variation in being wider at the middle. The fifth, sixth, and seventh leaves, with their stipules, are gradually smaller, but otherwise similar.

The actual number of scales in the buds of the Whitebeam varies a good deal, being fewer in the small buds, as well as in the large ones containing an inflorescence. The outer scales are coriaceous, the inner ones membranous. The bud sketched was examined towards the end of April, when the inner scales had commenced to push out at the apex.

The leaves are covered, especially on the under side, with white felt. Whatever may be the position of the branchlet, they stand quite upright, with the under sides outwards (Pl. II. fig. 5), so that they form a succession of intensely white pillars.

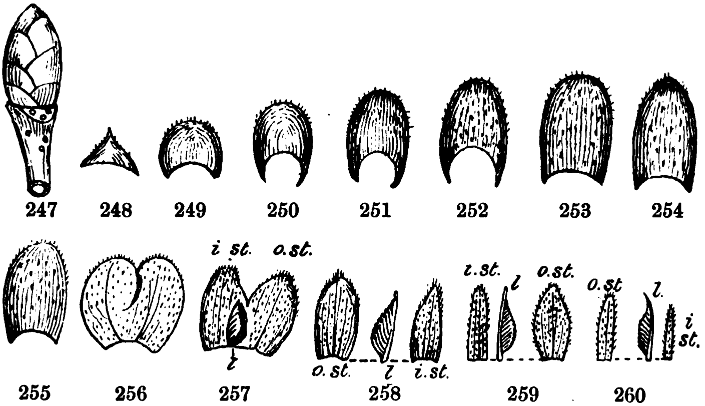
PROTECTION BY CONNATE STIPULES

ELM (*Ulmus*)

The buds of the common Elm (*Ulmus campestris*) (figs. 247–260), like those of preceding species, are covered and protected by scales, but there is an important difference. Each scale in the Beech or Oak represents a stipule. In the Elm each scale represents a pair of stipules. This is shown by the position and arrangement of the scales. The leaves are in two ranks, as in the Beech. Hence, as there are two stipules to each leaf, it follows that if each scale corresponded to a stipule they must be in four ranks, as, in fact, they are in the Beech (fig. 199). Those of the Elm, however (fig. 247), are in two rows, showing that each consists of two connate stipules.

This is further suggested by the fact that they are very often bifid at the summit, as is also shown in (fig. 256)—a further indication of their double origin. The young leaf, moreover, is situated, not between two scales, as in the Beech, but within and opposite the middle of the often bifid scale.

The outer four stipular scales are coriaceous, dark brown, brittle, more or less ciliate towards the apex.



Elm (*Ulmus campestris*).

Fig. 247.—Terminal bud, showing seven scales.
Fig. 248 —The first scale Fig. 249.—The second scale. Fig. 250.—The third scale.
Fig. 251.—The fourth scale. Fig. 252.—The fifth scale. Fig. 253.—The sixth scale.
Fig. 254.—The seventh scale. Fig. 255.—The eighth scale.
Fig. 256.—The ninth scale, showing fusion, which is unusual.
Fig. 257.—Members at the tenth node: *o.st.*, outer stipule with a portion removed to show the leaf, *l*, which comes next in order; *i.st.*, inner stipule.
Figs. 258-260.—Members at nodes 11 to 13; *o.st.*, outer stipule; *l*, leaf; *i.st.*, inner stipule. All are separated to show outline.

Owing to their being connate, however, the single piece occupies the central position of the leaf, the blade of which, if present, would be between them. These four scales do not elongate in spring, being practically dead; they often split at the apex into four or five teeth.

The first scale (fig. 248) is widely triangular and generally sharply cuspidate. The second (fig. 249) is nearly orbicular, deeply concave, and covers a considerable portion of the bud. The third (fig. 250), fourth (fig. 251), and fifth (fig. 252) are more oblong, gradually longer, each covering a large portion of the bud and overlapping the scale next above them. The fifth is more membranous and pubescent, remains alive during winter, and elongates on the resumption of growth in spring. It is strongly or copiously ciliate, particularly above the middle. The sixth (fig. 253) is longer, but otherwise similar.

The seventh scale (fig. 254) in an average bud is the longest, covers about three-quarters of the bud, and being folded over or round the top of the bud, all the scales that follow are slightly shorter. The eighth (fig. 255) is more narrowed at the base. All these scales from the fifth onwards are furnished with longitudinal slender veins, running almost parallel from base to apex.

The ninth scale (fig. 256), in the bud from which the sketches were made, was divided halfway down, one lobe overlapping the other. Each half was furnished with a distinct midrib, with a few more slender veins proceeding from it. Other buds contained several more or less divided scales. Here we have evidence of these scales being made up of two stipules.

The tenth node of the same bud bore two perfectly distinct, broad, oblong stipules, with a leaf between them (fig. 257). Other buds showed that the fifth or often the seventh scale had reached this stage; so that individual buds vary according to size, vigour, and other circumstances. The stipules have a midrib and overlap one another. All the leaves are conduplicate, alternate, and distichous; and as they lie against the sides of the axis, with their edges to the sky, it follows that when figured on a flat surface their edges appear to be turned in opposite directions at each alternate leaf.

The eleventh pair of stipules (fig. 258) in the same bud were very unequal, the outer being the larger, oblong, and having the edges of the leaf lying beneath it as usual. The inner stipule was oblong-subulate. The stipules of the twelfth pair (fig. 259) were also unequal, the larger one being oblong-lanceolate and the smaller linear. The leaf-blade equalled its stipules in length. The thirteenth pair (fig. 260) and the fourteenth were unequal in length and width, but both linear. The leaf-blades of these two were longer than their stipules, but the slender apex is sometimes, at least, crumpled up beneath the apex of the stipule.

The larger of the two stipules of each leaf lies on the upper side of the branches or shoots bearing them. The leaves are all conduplicate in bud, acuminate, and penninerved, with closely approximate nerves. The two parts of the leaf are unequal, but this is scarcely discernible in the bud. The broader part lies next the axis, as in the Lime.

Henry (18, 308) regards the outer scale as a combination of the leaf-blade with the two stipules. I see, however, no sufficient reason for this view.

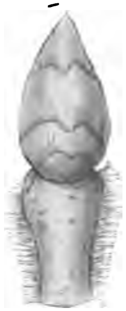


FIG. 261.—BUD OF WYCH ELM.

As the leaves come out the shoot curves down, and the stipules form arched hoods over the young leaves. They are often bright pink and very pretty.

In the Wych Elm (*Ulmus montana*) the construction and arrangement of the bud (fig. 261) resemble that of the Common Elm, but the double character of the outer scales was more clearly shown in the specimens I examined. Fig. 262 gives the four outer scales. The inner ones pass gradually into pink, from a greyish green base. The young bud (Pl. III. fig. 1) is in a line with the branchlet, but as it expands it turns downwards and hangs at right angles to it (Pl. III. figs. 2–4). When the young shoot has reached the stage shown in

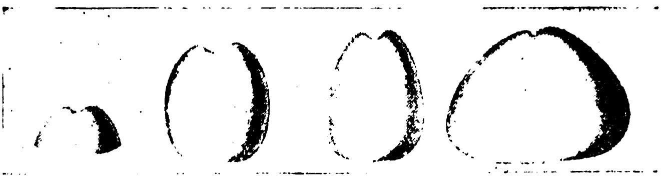
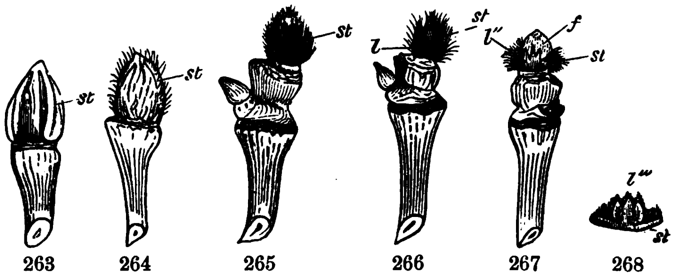


FIG. 262.—OUTER SCALES OF BUD OF WYCH ELM.

Pl. III. fig. 4, any slight touch is sufficient to detach the outer scales. A few days later the pink scales also begin to wither and fall off. The leaves then rise up again and assume their permanent position.

THE PLANE (*Platanus*)

The case of the Plane (*Platanus orientalis*) is also very interesting. If the base of the leaf-stalk be examined, it will be found, as already mentioned (*ante*, p. 6), to form a regular cap, protecting the bud (fig. 7). After the leaves have fallen the winter-buds are covered by several cap-like stipules, the leaves of which are not developed. The outer cap is brown or reddish brown, and has a gummy secretion on



Winter-bud of Plane (*Platanus orientalis*).

Fig. 263.—*st*, outer or first stipular scale, entire.
Fig. 264.—*st*, second stipular scale, glandular and slightly hairy, entire.
Fig. 265.—*st*, third stipular scale, very hairy, with a minute opening at the apex.
Fig. 266.—*st*, fourth stipular scale, very hairy, open at the apex; *l*, the first leaf.
Fig. 267.—*st*, fifth stipular scale, now much shorter than the bud and open at the top, showing an inflorescence, *f*; *l''*, the second leaf, which is slightly 5-lobed.
Fig. 268.—*st*, sixth stipular sheath, now reduced to a narrow rim, hairy, and here spread open; *l'''*, the third leaf, which is 5-lobed, with the two small lobes folded on the back of the leaf.

its inner surface, besmearing the bud, as in the Horse Chestnut, but only in the very early stages. As the bud swells the outer cap becomes ruptured, and appears then like a deeply concave scale, which is glabrous or nearly so. This cap is followed by others, which attain a somewhat larger size before the expanding bud causes them to split; they are densely covered with brown hairs externally and glabrous internally.

Fig. 263 represents the terminal bud of the leading shoots, and also of the lateral spurs or short twigs, covered with a conical, fluted, glabrous, reddish-brown cap, consisting of stipules which are connate to the very apex; the latter is slightly lateral, and all the ribs or veins terminate there.

Inside the first stipular cap comes a second (fig. 264), thinly hairy, dotted with dark glands and completely covered with a viscid, resinous secretion; the veins terminate at the apex.

The third cap (fig. 265) is also entire, but densely covered with glossy rich brown hairs; the latter have three to six very short, spreading branches at the very base, and consist of two to six joints, resembling a bamboo or fishing-rod, the joints becoming more slender towards the apex.

The fourth cap (fig. 266) is shorter, widely open at the apex, and provided with an ovate leaf at its base externally; both cap and leaf are covered with brown hairs.

In the bud figured the fifth (fig. 267), sixth (fig. 268), seventh, and eighth scales show a leaf with the free portion of the stipules forming auricles, and the connate portion forming a short cylindrical sheath. The number, however, differs slightly in different buds.

Inside the above in all the large buds comes a spike of heads or clusters of fruits (*f*, fig. 267), the heads so arranged as to form a conical mass inside the various caps and short cylinders formed by the stipules.

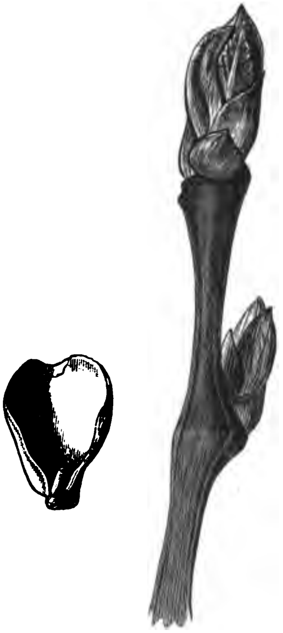


Fig. 269.—Bud of Spanish Chestnut, 1½ nat. size; the second scale detached, × 4.

THE SPANISH CHESTNUT

(*Castanea vesca*)

The scales which protect the bud of the Spanish Chestnut (*Castanea vesca*) (fig. 269) are also connate stipules; this is indicated by their being frequently indented at the apex. The outer one is dry and brown. The second scale (fig. 269) is longer and greener. Its true character is shown not only by the indentation at the summit, but by the presence of a rudimentary bud at the base, which is situated, not at the side, as it would be if the scale were a single stipule, but opposite the centre.

The following pairs of stipules are separate, hairy, and about as long as their leaf, which is conduplicate, but the sides do not touch as they fold over the inner leaf. The next leaf and its stipules are similar. The fifth pair of stipules are narrower, and rather shorter than their leaf. The following stipules become quite narrow. The leaves are conduplicate.

PROTECTION OF THE BUD BY CONNATE STIPULES BELONGING TO DIFFERENT LEAVES

In the previous cases the two connate stipules were the pair belonging to a single leaf. In the Hop (*Humulus Lupulus*) (figs. 270, 271) the two stipules which have coalesced belong to two different leaves. The stipules are large, develop early, and cover not only the rest of the bud, but their own leaves also.

Henry (18, 268) regards the stipules covering the bud of the Hop as representing the stipules of a pair of leaves which are otherwise undeveloped. The explanation above given seems, however, to be more in accordance with the facts.

A similar case is afforded by those species of *Stellatæ* (*Galium*) which have leaflets in whorls of four.

In *Elatine Alsinastrum*, also, the stipules are united each to the neighbouring stipule of the opposite leaf, so that the stipules equal the leaves in number.

CONIFERS

The buds of Conifers are constructed on a very different plan.

That of the Scotch Fir (*Pinus sylvestris*) (figs. 274, 275) is covered by brown, elongated scales, which are spirally arranged on the axis, and represent the primary leaves. They rest on a pedestal or base (fig. 273), which in the winter is green, and from which they are easily stripped off, leaving a whitish scar.

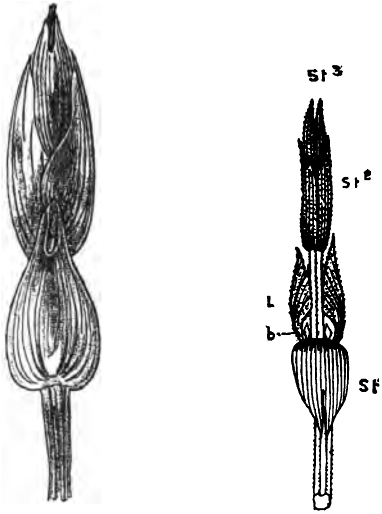


FIG. 270. FIG. 271.

END OF SHOOT OF THE HOP.

FIG. 270.—Stipules in their natural position, × 3.

FIG. 271.—Lower stipules turned back, exposing a protected leaf (L) with its axillary bud (*b*) on each side of the stem; st^1, st^2, st^3, stipules at successive nodes.

The bud may be divided into three parts. The lower, which occupies from one-fifth to one-tenth of the length, is somewhat narrower than the rest. No needles are developed on this part of the bud. The middle portion is the longest, and when the brown portion of the primary leaves has been stripped off has, from their spiral arrangement, very much the

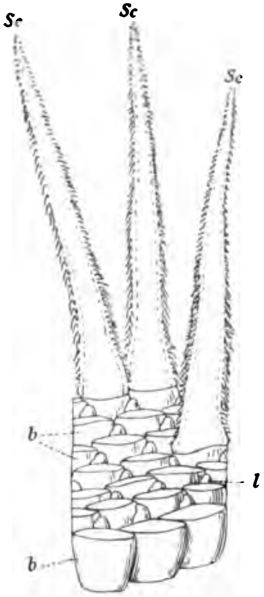


FIG. 272.

FIG. 273.

SCOTCH FIR (*Pinus sylvestris*).

FIG. 272.—Fragment of terminal bud representing seven tiers of scales of the winter-bud, × 6; *Sc*, three scales with their fringed membranous margin, the rest have been removed; *b*, persistent bases of scales; *l*, buds of secondary leaves in the axils of the primary.

FIG. 273.—A detached scale-base.

appearance of an elongated cone. At the base of each pedestal is a small axillary bud, bearing the secondary leaves or needles in pairs. The brown, terminal part of the primary leaves is thrown off in spring, and these secondary leaves form the 'needles.'

The brown, primary leaves are thicker towards the centre, and thin off towards the edges. They consist of diverging fibres connected by a thin membrane.

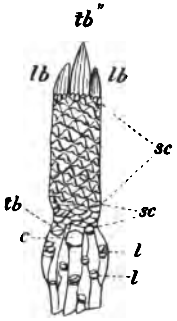


FIG. 274.

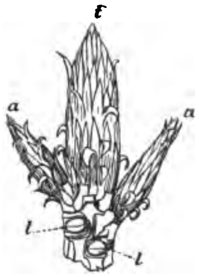


FIG. 275.

SCOTCH FIR (*Pinus sylvestris*).

FIG. 274.—Terminal bud; *sc*, bases of primary leaf-scales which have been removed, revealing the axillary foliage-leaf buds; *tb''*, terminal bud of next year; *lb*, lateral bud.

FIG. 275.—Apex of branch, ×2; *t*, terminal bud; *a*, axillary buds at the base of the terminal; *l*, base of pair of secondary leaves or needles.

Towards the edges the fibres turn suddenly backwards, and are frayed at the edges, forming an interlacing tissue, which helps to strengthen the bud (fig. 272). These scales are very numerous. Some of the outer ones are truncate (fig. 275). These are followed by a few that are triangular, subulate, acuminate. Succeeding scales pass quickly from triangular to more decidedly subulate forms, which are more or less revolute at the tip. They are followed by a few more which are linear, with a subulate base, and revolute at the tip.

These scales with revolute tips are followed by a dense mass of others which are subulate-linear, acuminate, straight, and closely adpressed to the bud.

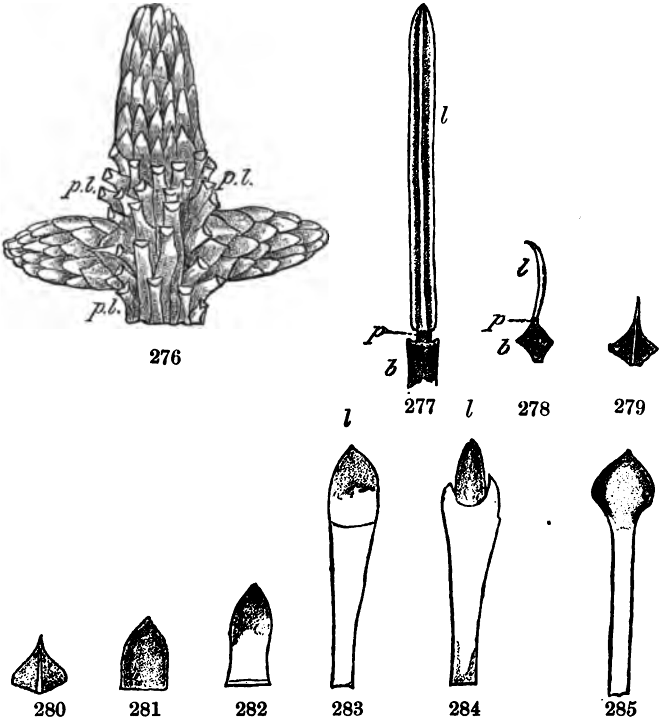
If a large terminal bud is taken, and the scales removed, it will be seen that the bud includes the whole of the plan of growth for the two succeeding years (fig. 274). The scales themselves are the primary leaves of next summer's shoot; and their obovate, persistent bases constitute the persistent scales upon the primary axis.

In the axils of these persistent portions, which are green in winter, we find the axillary buds which go to form the secondary shoots upon the resumption of growth in spring. In those buds containing male catkins, the latter are equivalent to axillary shoots, and occupy the lower portion of the axis of the bud; while the perfect leaves are similarly accommodated, but higher up the axis of the large resting winter-bud.

At the apex of this bud we find two or more relatively large ones, which are the resting buds of the succeeding year. The scales covering them are already testaceous, but await the following summer before making further progress.

Thus the primary leaves of two seasons' growth take part in the composition of the winter-bud.

In the Spruce Fir (*Picea excelsa*) the winter-buds (fig. 276) vary greatly in size, those at the apex and



Spruce Fir (*Picea excelsa*), × 3.

Fig. 276.—Apical and two lateral buds; *p.l.*, pedestals of leaves after the green portion has been removed. **Fig. 277.**—Normal and perfect leaf; *l*, leaf; *p*, pedestal; *b*, basal portion decurrent upon the axis. **Fig. 278.**—Slightly modified small leaf; *l*, leaf; *p* and *b*, pedestal and base merged in one another. **Figs. 279, 280.**—Leaves now modified to triangular acuminate scales with a midrib. **Figs. 281, 282.**—Succeeding forms of scales. **Figs. 283, 284, 285.**—Inner scales after they have elongated, about the middle of April; *l*, *l*, in Figs. 283, 284, would seem to represent the lamina, surmounting elongated pedestals; the same portion in Fig. 285 is hooded over the apex of the bud; the lower portions are membranous and transparent.

immediately beneath it being strongest on the leading branches; they are also the first to resume growth in spring. All are covered with numerous scales, which consist of modified leaves. The actual number of scales varies greatly, according to the size of the bud. The accompanying figures would represent buds and scales about the middle of April, after growth has recommenced. The outer scales are the most coriaceous, and elongate slightly or not at all; the inner ones are transparent and membranous, elongating considerably in spring.

The true leaf (fig. 277) consists of a lamina, which becomes disarticulated (when about to fall) from a short persistent portion or pedestal, surmounting a basal portion which is decurrent upon the axis. Fig. 278 shows a small, slightly modified leaf—a form which occurs but sparingly.

The basal portion of the bud is covered with broad, triangular, acuminate scales (figs. 279, 280), with a more or less evident midrib, which seem to consist of the whole leaf modified. These are followed by a few oblong, obtuse, or subacute scales (figs. 281, 282) that are still coriaceous, but elongate slightly in spring in the case of the inner ones.

The innermost scales (figs. 283, 284, 285) are as long as the bud, or nearly so; but after the resumption of growth they soon extend beyond the coriaceous ones, keeping pace for a time with the elongating axis, and completely enclosing the young true leaves. These inner scales elongate chiefly in the lower portion, which seems to correspond to the pedestal. They are, on the whole, more or less spathulate, but vary in form, and the apical portion seems to correspond to the lamina, because there is generally a trace of a joint or articulation. This apical portion is slightly more coriaceous and browner than the long and very membranous lower portion.

Some of the inner scales are more or less evidently trifid (fig. 284) or tridentate, the lateral lobes appearing to correspond to the shoulders seen below the pedestal of the normal and perfect leaf. The innermost scales (fig. 285) are suddenly widened at the apex, forming a hood or cap rolled round the apex of the bud and completely covering and protecting the young leaves.

CYCADACEÆ

In Cycas (*Cycas revoluta*) one tier of leaves is produced every year, all developing simultaneously. The bud is covered with a mass of imbricate scales. The latter are subulate, elongate, ending in a spine, dilated and triangular at the base, densely covered with a pale brown, woolly felt, erect or incurved in bud, ultimately spreading with age, but persisting for many years. Thus two sets of leaves are developed every year, each tier duly alternating.

In *Zamia* also (*Zamia Fischeri*) the buds are protected by numerous scales.

CHAPTER VI

ON THE FORMS OF STIPULES

THOUGH stipules do not show such endless differences in form as is the case with leaves, nevertheless they present an immense variety.

They may be orbicular, as in *Tropæolum ciliatum* (fig. 312); semi-orbicular, as in *Guaiacum officinale* (fig. 30); ovate, as in *Passiflora racemosa*, Hop (fig. 47), and *Abutilon megapotamicum*; obovate, as in *Bucklandia* (fig. 190); oblong, as in *Leea* (fig. 188) and Alder (fig. 145); elliptic, as in Hazel Nut (fig. 212); spathulate; lanceolate, as in *Paronychia serpyllifolia* and *Pyrus japonica*; linear, as in *Disanthus* (*Hamamelideæ*) and *Ficus infectoria*; filiform, as in Turkey Oak (*Quercus Cerris*); subulate, as in *Mahonia* and several species of *Helianthemum*; sagittate, as in *Lathyrus pratensis* (fig. 299) and *L. maritimus*; semi-sagittate, as in *Lathyrus latifolius* (fig. 300) and *L. grandiflorus*; reniform, as in *Vallea* (*Sterculiaceæ*); triangular, as in *Ceanothus rigidus*; boat-shaped, as in *Populus nigra* (fig. 192); palmately lobed, as in *Croton*; laciniate, as in *Trigonella laciniata*; pinnatifid, as in several species of *Croton*, *Medicago* and

Melilotus; pinnatipartite, as in *Viola tricolor* (fig. 27), *Passiflora pinnatistipula*, and *Pomaria glandulosa*; or palmatipartite, as in *Althœa rosea*, *A. ficifolia*, *Pterospermum acerifolium*, &c.

In texture they may be foliaceous, as in the Heartsease; membranous, when thin, flexible, and almost transparent; scarious, when dry and coriaceous, as generally in the Beech and Hornbeam; spinous, as in *Robinia* (fig. 34); cirrhose, when produced into tendrils, as in Smilax.

In many cases the stipules are very small, sometimes quite minute, as in *Hymenanthera* (fig. 28), a plant belonging to the Violet family. The Holly is described in Bentham and Hooker's 'Genera Plantarum' as exstipulate, but (fig. 29) there are minute black points at the base of the leaves, which appear to represent stipules. In others they are very large, as in the common Pea (*Pisum sativum*) (fig. 26), *Lathyrus maritimus* (fig. 296), and *Bucklandia* (fig. 190).

Many plants have stipules of different forms.

The stipules covering winter-buds are often different in form from those of the subsequent leaves (see, for instance, figs. 215–235).

Where stipules serve as bud-scales there is generally a series of different forms, from those of the outer scale to those of the ordinary leaf.

In the Thorn (*Cratægus Oxyacantha*) (fig. 286) the stipules on the leaves of the short lateral spurs and those at the very base of the elongating shoots are minute and toothlike, or subulate, soon becoming brown and falling early. Those on the upper part of the elongating shoots

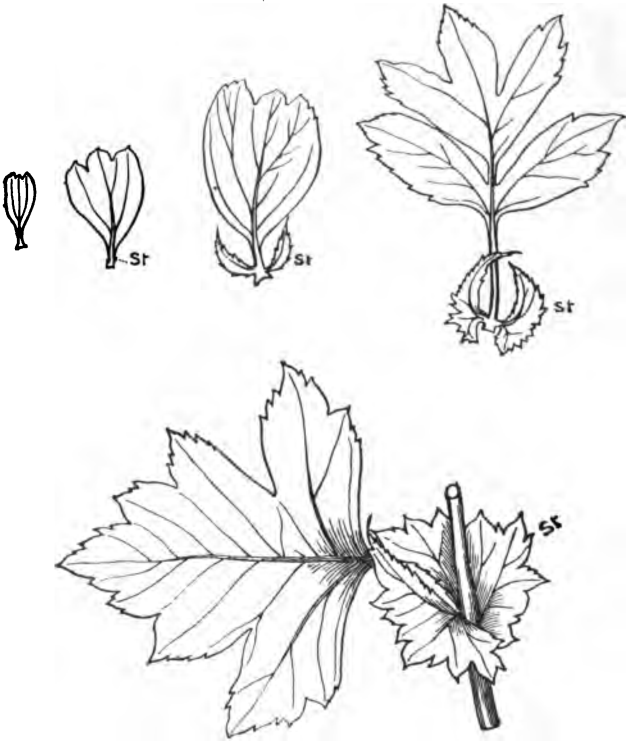
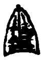


FIG. 286.—LEAVES OF HAWTHORN.

vary from unilateral, falcate, serrated, small but foliaceous organs, to large, half-cordate, simply or doubly serrate, shortly stalked, foliaceous, much-reticulated organs, with the principal nerves radiating from the base of the lamina and passing into the principal teeth. Thus there are at least three distinct types of stipules.

These differences are probably connected with the differences in the shoots. These may be described as of two kinds, namely, those which develop into more or less lengthy, leafy shoots, which go to increase the height and breadth of the tree, and those which form short lateral spurs. The latter are very numerous, forming dense rosettes of leaves, and produce clusters of flowers in profusion in adult bushes and trees. Owing to the crowded state of their leaves, the bases of their petioles occupy the whole, or very nearly the whole, of the surface of the short axis, thus leaving little or no space for stipules. The lower or outer leaves are very small, and entire, or tridentate, or trifid, with short petioles. Very often these have no trace of stipules. The inner or upper leaves of these rosettes are better developed, with elongated petioles, so as to enable them to extend beyond and occupy the space between the short ones. This is obviously a provision to expose every leaf to light. The stipules of these longer-stalked leaves vary from mere points to subulate or linear, small, brown organs, which being relatively functionless after the expansion of the leaves, soon shrivel up and fall away.

At or near the base of the elongated leafy shoots fairly well-developed leaves occasionally occur, which have no stipules; but as a rule the stipules in this position are also well developed (fig. 286). As these shoots elongate and become vigorous, the internodes become longer, and the leaves and stipules larger. The latter, indeed, become



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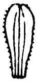

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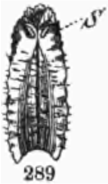

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Ribes sanguineum.

Fig. 287.—Outer bud-scale with three vascular bundles; stipules indicated by lateral teeth at the tip.
Fig. 288.—Inner bud-scale with broader membranous margin.
Fig. 289.—Intermediate form between bud-scale and leaf. *S*, stipule.

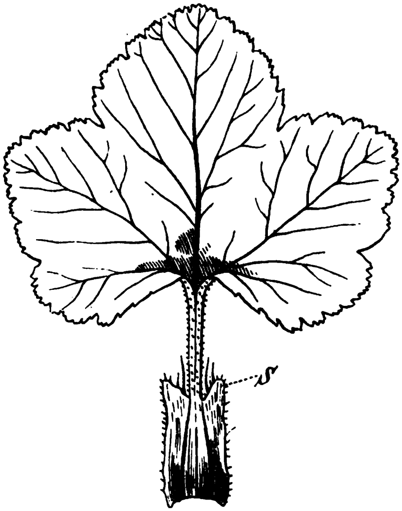

Fig. 290.—Ribes sanguineum.
Leaf higher up on shoot. *S*, stipule.

quite leafy, and supplement the area of the foliage. This is, doubtless, an advantage, as the leaves themselves do not by any means utilise the area at their disposal, as do those of the Lime, Beech, or Elm.

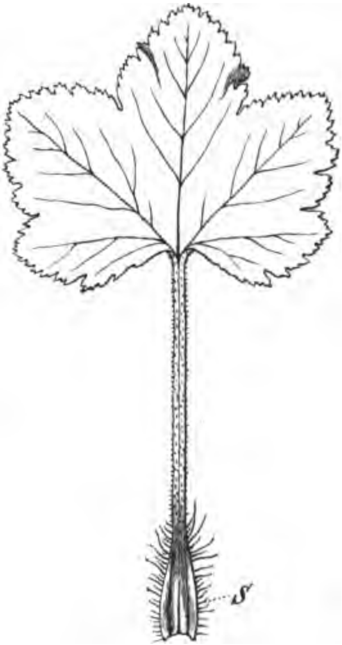

FIG. 291.—RIBES SANGUINEUM.
A fourth stage, showing stipules reduced to an adnate sheath, *S*.

Only smaller leaves and stipules have any relation to the winter-bud, the small size of which implies that relatively few leaves can at this time be developed. The flower-buds in the members of the *Rosaceæ* are usually more advanced early in spring than the leafy ones, as they flower in spring.

In the Quince (*Pyrus Cydonia*) we have the following series: 1. The scales of the winter-bud are very broad, short, deeply trifid or almost tripartite, deep brown or black; the lateral lobes are the largest, and represent the stipules. 2. Fascicles of leaves are produced along the sides of the previous year's wood, and the stipules on the outer leaves are reduced to small blunt teeth. 3. Those towards the centre of the fascicle bear subulate or linear stipules, with a distinct midrib. 4. On the base of the elongating shoots the stipules are lanceolate, shortly stalked, acute, and one-nerved. 5. The stipules gradually widen on succeeding leaves, till they become broadly and obliquely reniform, dentate, with the midrib nearest the anterior side and running into an acute point, copiously reticulate, shortly petiolate, and foliaceous, with large auricles passing round the axis until they meet on the opposite side. The scales of the winter-bud persist for some time, at least, after the expansion of the leaves, and offer some protection. There would be no need, nor room, for large stipules in the fascicles of leaves, as the older leaves protect the younger.

Again, in the Currant (*Ribes sanguineum*) about five (more or less) of the scales of the winter-bud are ovate, acute, trinerved, rather membranous, and consist of the dilated base of the petiole, the lamina being represented by a small black point (fig. 287). One or two succeeding ones bear a small lamina sessile on the sheath, which is wholly adnate to the thin, dilated base of the petiole, and membranous, especially outside of the three vascular bundles (fig. 289). One or two of the leaves succeeding this have a well-developed lamina, and the sheaths partly separated from the petiole and corresponding to stipules (fig. 290). The stipular sheaths on succeeding leaves are shorter and wholly adnate to the petiole, strongly fringed on the margin, with the hairs on the upper portion longest and more or less branching (fig. 291).

This series is shown in figs. 287–291.

POTENTILLA

Most of the species of *Potentilla* are herbaceous perennials, some with evergreen, others with deciduous leaves. The different forms of stipules found on the same plant appear to have reference to its habit. Usually a large number of the leaves are radical, springing from the crowns or growing-points of the rootstock, which is often buried to a greater or less extent in the soil. The long stipules, adnate to the petioles, and more or less completely overlapping the younger members, form a very effective protection to the buds, either while resting, or while pushing up their young leaves and flowering stems from beneath the soil. The stipules of these leaves sometimes remain beneath the soil, sometimes rise above it to a greater or less extent; in the latter case they are usually much crowded and overshadowed by the leaves. Judging from these facts, and that they are colourless or soon become brown, their sole function would appear to be that of protecting the young stems and leaves. The crowded state of the petioles, the want of space, and their being buried in the soil or overshadowed by the blades of the leaves, hinder any further development of the stipules.

Even where the rootstock is woody and rises above the soil, the petioles are usually much crowded, so that here again the sole function of the stipules would appear to be one of protection.

The stipules of the cauline leaves gradually become shorter, broader, and more foliaceous higher up the stem. In the bud state these stipules are thoroughly effective in protecting the younger members of the bud; but being often as green and of the same texture as the leaves themselves, they perform also the function of leaves, or, in other words, increase the leaf surface of the plant, as well as being protective in their earlier stages. In cases where they assume the greatest width at the apex of the plant, they do so for the accommodation of the inflorescence. This case is better exemplified in *Trifolium*, which will be described subsequently. We have a rather extreme case in *Potentilla Tormentilla*, where the stipule of the cauline leaves resemble leaflets.

In all the species examined the stipules owe their modifications to crowding, the obstruction of light, or exposure to the same, and to the form or position of the buds they have to protect.

Sometimes the gradation is regular. Thus, in *Nuttallia cerasiformis* the winter-bud is covered with numerous scales, which are leaves wholly reduced to their sheaths. The outer ones are very short, rounded, ovate, or triangular, not lengthening when growth commences; the inner ones lengthen, becoming linear, cuspidate, concave, rolled round the bud, pale green, almost colourless, membranous, and ciliate at the margin.

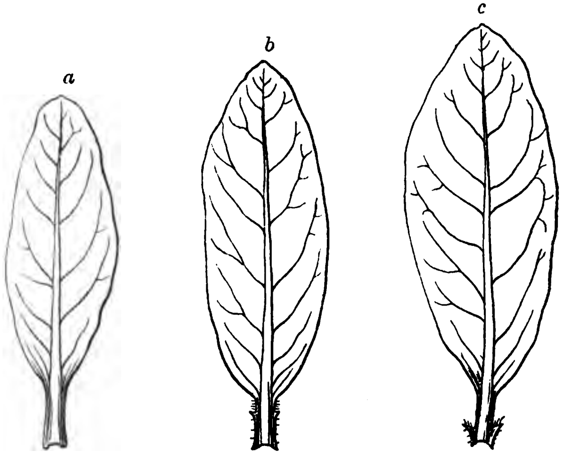

FIG. 292.—LEAVES OF NUTTALLIA CERASIFORMIS.
a, with entire sheath; *b*, showing indications of stipules; *c*, with stipules in ultimate form.

The first leaf in the bud having a lamina is spathulate, with the petiole transformed into a grooved sheath, membranous at the margin right up to the base of the lamina; the second and third leaves have a similar but shorter sheath and oblong lamina (fig. 292, *a*); the fourth leaf is oblong or oblanceolate, with the membranous sheath partly separated from the petiole, and forming stipules still adnate for the greater part of their length (fig. 292, *b*); the fifth and sixth leaves are similar, with shorter petioles and shorter, but more evident, stipules (fig. 292, *c*). Here, then, we have in the bud a gradual transition from leaves wholly reduced to sheaths to those with a lamina and a sheath, then to those with a lamina, petiole and stipules, the latter being adnate to the petiole for a greater or less part of their length.

Several other species of *Rosaceæ*, belonging to various genera (*Cratægus*, *Geum*, *Pyrus*, *Potentilla*, &c.), present us with cases of polymorphic stipules.

Exochorda Alberti, a member of a small Central Asiatic genus, is a very curious case. The lower leaves have well-formed stipules at the base of the leaf-stalk (see *ante*, fig. 53, p. 39). Gradually the base of the leaf-blade elongates and the true petiole shortens, so that the stipules are attached higher and higher up, nearer and nearer to the blade. The upper leaves have a tooth at the base, which, however, is very variable, and often absent on one side. Finally, the uppermost leaves generally show no trace of stipules or teeth.

As a general rule the two stipules of the same leaf are similar in form, but in some cases they are more or less dissimilar.

Thus, in *Azara dentata*, a plant from Chili belonging to the exotic family *Bixineæ*, the two rows on the upper side of the branches are foliaceous and evergreen, resembling the leaves in shape, toothing, texture, and hairiness, while the two rows on the lower side of the branches are minute, subulate, hairy, and brown or black in winter. The two sets are also very unequal in *A. microphylla* and *A. Gillesii*. In *A. celastrina*, on the other hand, both series are minute.

Again, in *Abutilon megapotamicum* the stipules are ovate, acute, concave, unequal at the base, the side away from the petiole being the larger, and that next the petiole cut away; they are unequal in size, that on the upper side of the drooping branches being broader, and often longer, than that on the under side. They appear to be about as persistent as the leaves, and amply protect the terminal buds.

In *Diplophractum*, a genus of *Sterculiaceæ* from Java, the stipules are also dimorphic. Both are leafy and bullate, but while one of each pair is bifid and bristly, the other is entire.

In *Ervum monanthos* (fig. 293), a leguminous forage plant, one of the stipules in each pair is small and subulate, the other comparatively large and deeply cut into narrow segments. The larger one shows considerable variation in size and the amount of its segmentation.

Catha edulis (*Celastrineæ*), a native of Arabia, where it is cultivated and its leaves used for making a beverage comparable with tea or coffee, presents us with another interesting case of stipules of two kinds on one leaf.

The leaves are alternate, elliptic or obovate-elliptic, serrate, leathery and persistent; the petiole is short, rather deeply grooved above, prominently edged, scarcely dilated at the base, and articulated. The stipules are of two kinds. The outer set of stipules are subulate, with a strong midrib and a ciliate margin, erect, adpressed to the axis, and having the anterior half lying in front of the petiole. They are semi-persistent, but many of them fall during the first winter. The other set of stipules consist of coarse fringes or ciliæ, not unlike the ramenta of ferns, and are intrapetiolar, extending in front of the true stipules and the petioles. When the outer ones fall the plant appears to possess these fringes only. The 'Genera Plantarum' (vol. i. p. 361) says, 'Stipulæ e ciliis paucis,' and seems to refer to these fringes only.

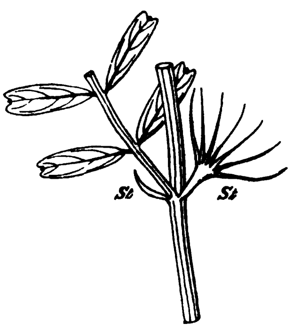

FIG. 293.—ERVUM MONANTHOS. *St*, *St*, stipules.

The terminal bud (at least in the resting stage) is completely covered by the true stipules, and further protected by the petioles of one or more of the last-developed leaves, which are either small or imperfect.

But few attempts have yet been made to explain the differences in the forms of stipules. Some have been indicated in the preceding pages, and it may be interesting to refer to a few cases in more detail. For instance, among the Clovers (*Trifolium*), the common Red Clover (*Trifolium pratense*) has the strongly veined connate stipules (fig. 294) ovate, the free part short, triangular, and ending in a setaceous, applied point. The upper ones are somewhat dilated. In White Clover (*T. repens*) (fig. 295) they are all comparatively narrow, and subulate at the free end.

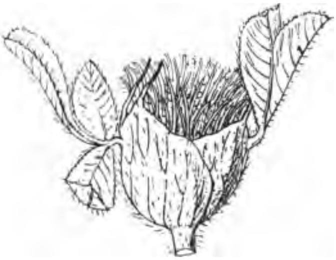

FIG. 294.—TRIFOLIUM PRATENSE.
Flower-bud with the pair of protecting leaves. Nat. size.

This difference may perhaps be accounted for by the different arrangement of the flower-bud. In *T. pratense* the head is sessile (fig. 294) and the bud is protected by the broad stipules. Hence, also, perhaps the upper ones are more dilated than the others, as they have to cover the young flower-head. In *T. repens*, on the contrary, the peduncle elongates (fig. 295), while the flower-head is still very undeveloped, indeed, scarcely broader than long, and without any projecting corollas. The young flower-head pushes out from the plant and lies flat on the ground, selecting a suitable situation for its development. Fig. 295 shows a bud in an early state, the corollas quite uncoloured and enclosed by the calyces, but already with a long peduncle carrying it far beyond the stipule, *st*. *T. medium* also has stipules much narrower than those of *T. pratense*.

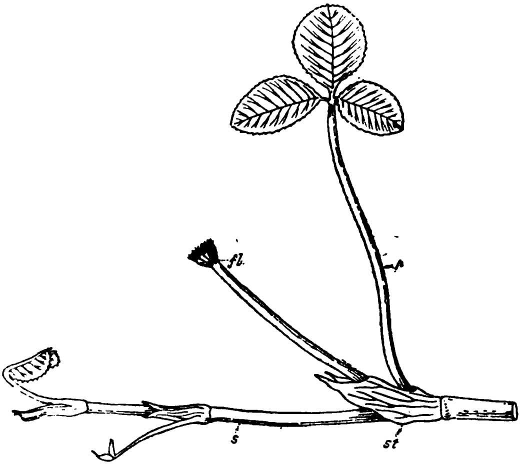

FIG. 295.—TRIFOLIUM REPENS.
End of creeping shoot. *s*, stem ; *st*, stipule ; *p*, leaf-stalk ; *fl*, very young flower-head. Nat. size.

In the Peas and Vetches the stipules vary greatly in size and shape. Some are large and broad, some long and narrow; these again being in some cases sagittate, in others half-sagittate.

Lathyrus maritimus belongs to the first category. The stipules (figs. 296 and 297) are large, foliaceous, and develop early. The stipules of the common Garden Pea have already been described and figured (see *ante*, p. 23).

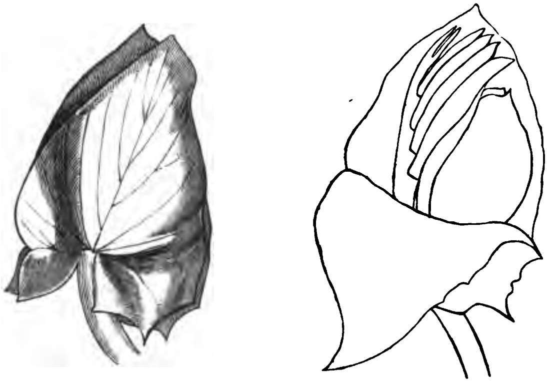

FIG. 296. FIG. 297.

STIPULES OF LATHYRUS MARITIMUS. One-and-a-half nat. size.
In Fig. 297 one of the stipules is turned back, revealing the rest of the leaf and bud.

In *L. grandiflorus* (fig. 298) they are small, half-sagittate, narrow, and pointed. The upper and lower limbs, moreover, do not lie in the same plane, but are somewhat twisted relatively to one another.

In other species, as for instance in *L. pratensis* (fig. 299), they are sagittate.

Now, if we open the bud of *L. maritimus* (fig. 297), we find that the young leaves and stipules occupy most of the space between the outer stipules, which cover and protect both the leaves and stipules of all the younger ones, as well as the inflorescences and their own leaf in its earlier stages. They are sessile, cordate, unequally sagittate, and glabrous like the rest of the plant, with numerous strong nerves radiating from the point of their insertion on the axis. The smaller auricle is generally ovate or triangular and entire; the larger one has three or four cusps or teeth. The stipules form a very efficient protection to the leaves till they attain a considerable size.

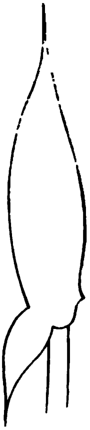

Fig. 298.—Stipule of Lathyrus grandiflorus.

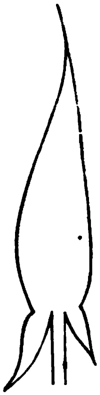

Fig. 299.—Stipule of Lathyrus pratensis.

One-and-a-half nat. size.

In *Lathyrus latifolius* (fig. 300) the upper limb of the stipule also protects the younger leaves, which, however, have only one pair of leaflets, and not, therefore,

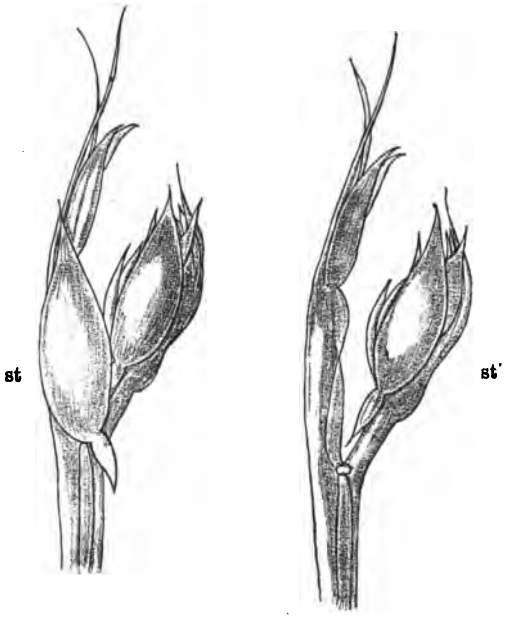

FIG. 300. FIG. 301.

STIPULES OF LATHYRUS LATIFOLIUS. One-and-a-half nat. size.
The lower stipule (*st*) in fig. 300 has been removed in fig. 301, exposing the whole of the stipule (*st'*) of the next higher leaf.

occupying so much room, do not require such wide stipules. The stalk, however, being very wide, is not entirely covered by the sheathing stipule. Consequently, if the upper stipule had a lower limb on the outer side, the latter would be exposed. The lower limb, which is on the inner side, lies snugly ensconced between the stem and the older leaf (fig. 301). Moreover, the function of the stipule being to protect the young bud, it develops early, and when it is full-grown the lower limb (fig. 301) is equal in length to the internode below. Subsequently, however, the internode becomes much longer, while the stipule remains as before. But though the stipule may be correctly described as half-sagittate, it sometimes (see fig. 298) shows a minute tooth where the other barb would have been, indicating that it is descended from ancestors which had a barb on each side.

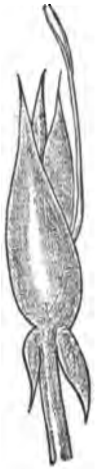

Fig. 302.

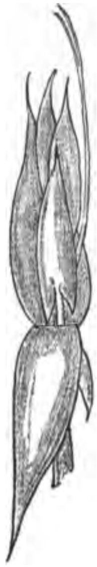

Fig. 303.

STIPULES OF LATHYRUS PRATENSIS. One-and-a-half nat. size. In fig. 303 one of the lower stipules is turned back, exposing the next younger leaf with its stipules.

In *L. pratensis* the stipules (fig. 302) are sagittate. Here, however, the petiole is round; the wings lie one on each side of it (fig. 303), and are fully covered by the stipule of the preceding leaf.

Thus, then, the difference between the sagittate and semi-sagittate stipules appears to depend on the form of the stem and the arrangement of the bud. Where the stem is winged the outer barb of the stipule would be exposed. In such cases the stipule is semi-sagittate.

In the Garden Pea (*Pisum sativum*) (fig. 26, p. 23) the stipules are not only large in bud, and in arrangement resemble those of *L. maritimus*, but they continue to grow, reaching a length of fully three inches and one-and-a-half in breadth, and act as a pair of leaflets, which they considerably exceed in size.

In *Lathyrus Aphaca* (fig. 305) the first and second leaves are scale-like and trifid, with three subulate points corresponding to leaf and stipules. The third and fourth leaves are compound, with one pair of leaflets and obliquely ovate stipules of considerable size, and having a tendril represented by a small subulate point.

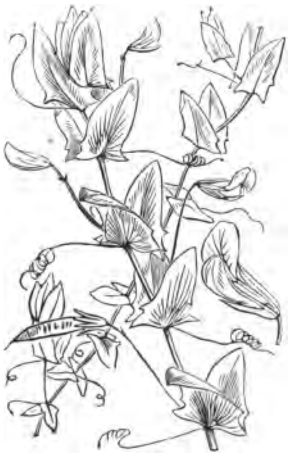

FIG. 304.—LATHYRUS APHACA.

The fifth and succeeding leaves are reduced to a subulate point and a pair of triangular, foliaceous stipules. The subulate point develops into a simple tendril on the middle and upper portions of the stem. The tendrils represent the leaves, and are alternate and distichous; that is, on the ½ plan of arrangement.

The stipules are arranged in two ranks, inserted on the stem at right angles to the tendrils. They increase in size as the plant gains in vigour, and become obliquely triangular-hastate, but continue flat in bud and afterwards. The venation consists of numerous parallel nerves, radiating from the point of insertion on the stem, the midrib being slightly the strongest (fig. 304).

Succeeding pairs of stipules overlap and protect all the younger members of the terminal and axillary leaf- and flower-buds and tendrils. All lateral buds come in the axils of the tendrils. The stipules, therefore, perform the double function of leaves and the work of protection.

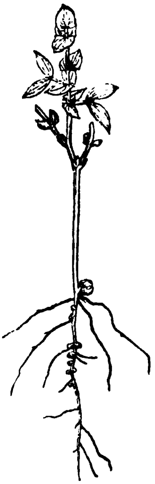

FIG. 305.—LATHYRUS APHACA. Seedling. Half nat. size.

A very interesting contrast is afforded by another species of *Lathyrus* (*L. Nissolia*), where the leaves are reduced (fig. 307) to a long, linear, grass-like, flattened leaf-stalk, ending in a fine point, and without leaflets. In the mature plant the stipules are almost obsolete, but in the seedling (fig. 306) the first and second leaves are subulate, acute, and scale-like, with small tooth-like or inconspicuous stipules. The third and all succeeding leaves are simple, entire, linear, slightly decurrent upon the stem, and have a strong midrib, with more slender parallel lateral nerves. They are alternate and

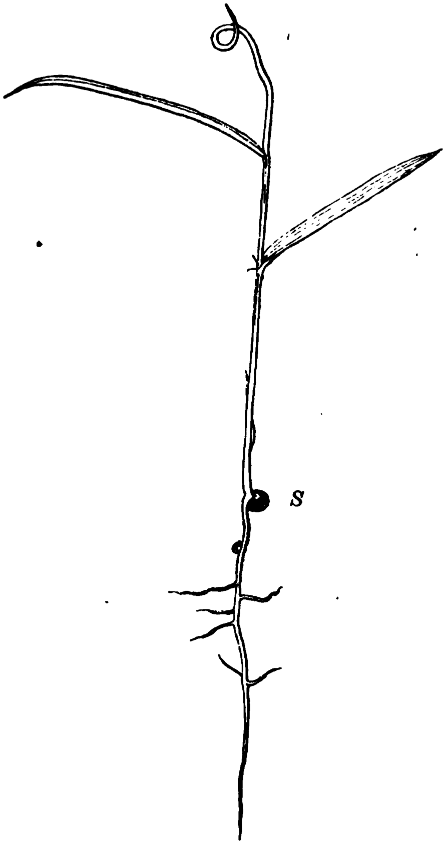

FIG. 306.—SEEDLING OF LATHYRUS NISSOLIA. Nat. size.
S, seed.

distichous—that is, on the ½ plan of arrangement—acuminate, and slightly narrowed to the base.

The third and all succeeding pairs of stipules are subulate acute, slender, gradually becoming shorter towards the apex of the stem, and inserted on the edge of the decurrent leaf, where it is narrowed, and below the articulation with the stem. They appear to be functionless owing to their minute size.

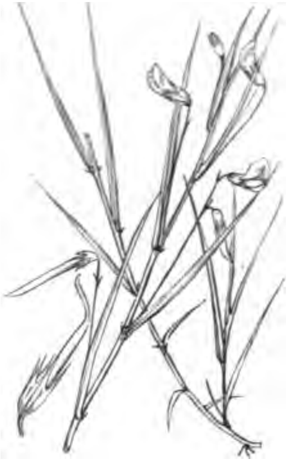

FIG. 307.—LATHYRUS NISSOLIA.

The terminal bud is enclosed in successive convolute leaves, which appear to be winged petioles without leaflets or tendril. They vary from three inches to six in length, and attain a considerable size before they unroll, after which they continue to be more or less concave, becoming slightly twisted. The axillary buds are sheltered in their axils. The terminal bud is amply protected by them. The plant forms a spreading tuft like a species of grass with coarse leaves.

The same causes which have led to the length and narrowness of the leaves of grass have probably influenced *Lathyrus Nissolia*, as well as other species which grow under similar circumstances. The resemblance is perhaps, also an advantage in preventing its being picked out and eaten by browsing quadrupeds.

CHAPTER VII

ON THE SUBSIDIARY USES OF STIPULES

THE general use of stipules is, as we have seen, to cover and protect the bud. This is, however, by no means the only function they perform. Though very often leafy, they are generally too small to be of much use as organs of assimilation.

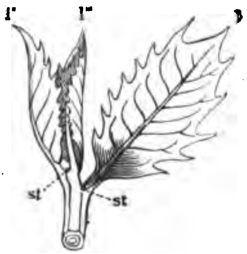

FIG. 308.—SHOOT OF HOLLY, showing successive leaves (l', l'', l''') and stipules (*st*, *st*).

There are, however, various gradations. Some, indeed, are quite minute, as in the Holly (fig. 308) and *Hymenanthera* (fig. 29, p. 24).

In other cases, though smaller than the leaf-blades, the stipules assist in performing similar functions. In some the assimilation must be trifling, as in the stipulate species of *Helianthemum*, in *Ribes*, and many others; in others it is substantial, though less than in the leaf-blades, as in the Roses; in others equal to that of the leaf-blades, as in the Pansy (fig. 309), where the stipules are large, oblong, and pinnatifid, with three to six linear lobes on the external side; or *Galium*

(Ladies' Bedstraw), where they are indistinguishable in form from the leaves.

Linnæus long ago pointed out that though the *Stellatæ* (*Galium*, *Rubia*, &c.) are generally described as having their leaves in whorls of four, six, eight, or more, there are, as a matter of fact, only two leaf-blades in the ordinary sense, and the other leaf-like organs are really stipules. De Candolle expressed the same opinion, and pointed out that buds are not produced at the base of all the foliaceous appendages, but only of those corresponding to true leaf-blades.[1] Where there are six leaflets, these correspond to two leaf-blades and their four stipules. Where there are only four leaflets, this is considered to be due to a coalescence of stipules by pairs, as in the case of the Hop.

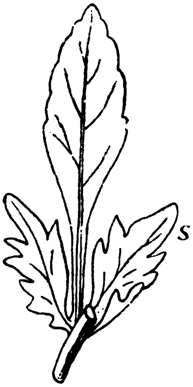

FIG. 309.—LEAF OF PANSY.
S, stipule.

Acacia verticillata (fig. 310) and some nearly allied species constitute an instructive and interesting case. *A. verticillata* has linear, pointed, laterally compressed phyllodes, arranged in whorls, so that it has very much the look of a strong *Galium*. Buds only occur here and there along the stem, and the phyllodes generally have no stipules, their presence depending on whether there is or is not a bud. If there is no bud, there are no stipules, while if a bud is formed, stipules are also developed.

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[1] *Praelect. in Ord. Nat. Plantarum*, 1792, p. 520.

In these and other similar cases the stipules must to some extent assist the leaves, which, however, are also well developed.

In *Lathyrus Aphaca* (fig. 304), on the contrary, as already mentioned, the leaf-blades have disappeared as assimilating organs, and are replaced by two large stipules, which are sessile, triangular, and provided with two large auricles, directed outwards.

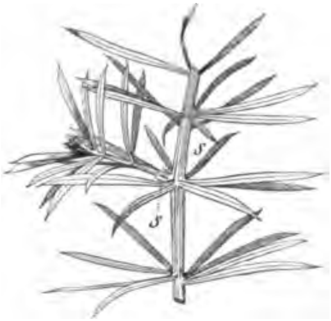

FIG. 310.—SHOOT OF ACACIA VERTICILLATA, × 1½.
S, *S*, stipules.

In some species of *Adesmia* (a South American leguminous genus) leaves are present only on the lower part of the long, straggling branches, the upper part bearing stipules only, which gradually pass into bracts (fig. 311).

In the *Urticaceæ* stipules are almost invariably present, and in their form and position afford good characters for the distinction of genera and larger groups. In the closely allied tropical genera, *Elatostema* and *Procris*, the leaves of succeeding pairs become more or less separated and very unequal, one being reduced to a very small blade, or it becomes quite suppressed and is replaced by the stipules. A similar reduction of leaf and replacement by the stipule occurs in *Forskohlea*.

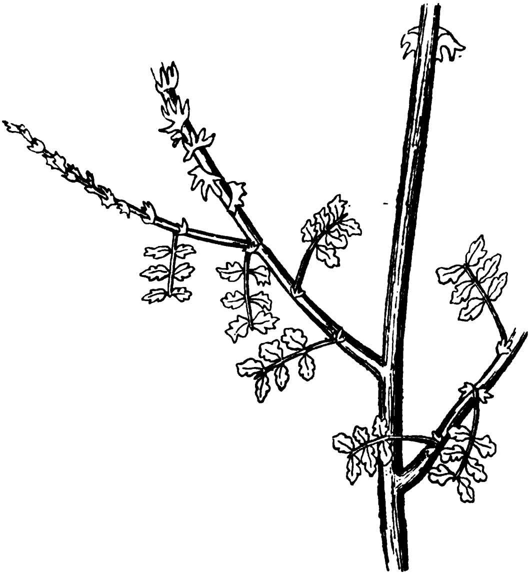

FIG. 311.—ADESMIA BRACTEATA. Two-thirds nat. size.

Rosa berberifolia, or, adopting the earlier name, *R. persica*, has been the subject of much difference of opinion as to presence or absence of stipules. The leaves are thus described by Ledebour: 'Foliis abortu nullis, stipulis connatis foliiformibus glabris.' Focke, however, who has recently elaborated the *Rosaceæ* for Engler's 'Pflanzenfamilien,' describes them as simple, without distinction (Ausgliederung) of stipules and leaflets. We have, in fact, an interesting exception to the universal stipulate character of the family in this species, which has simple, subsessile leaves. The stem is prickly, and the frequent occurrence of the prickles, sometimes in pairs, at the base of the leaf has led to their description as stipules; for instance, by Boissier in his great 'Flora Orientalis.' Its exceptional character has twice led to its separation from *Rosa* as a distinct genus—first by Dumortier, in 1824, who called it *Hulthemia*; and secondly by Lindley, who gave a figure in the 'Botanical Register,' tab. 1261 (1829), under the name *Lowea*, with the following remarks: 'It is time that botanists should disembarrass themselves of this ancient prejudice' (against using organs of vegetation to supply generic characters), 'and admit publicly that by which they are constantly influenced in private—*that important modifications of the organs of vegetation are sufficient to divide into genera species which do not essentially differ in the organs of fructification.*' Boissier keeps up the generic distinction, but Bentham and Hooker ('Genera Plant.,' i. p. 625) include it in *Rosa*; as does also Focke, who, however, considers it to be a distinct subgenus, characterised by its simple exstipulate leaf. It is a low bush found in the deserts of Persia and Turkestan.

The Beech, Hornbeam, Lime, Oak, and many other trees, afford instances where the stipules, though attaining some size, are caducous, more or less scarious, and do not serve for protection nor for assimilation.

STIPULES CONVERTED INTO SPINES

In some species, belonging to very different families, the stipules, or some of them, are converted into spines, as, for instance, in some Acacias, Mimosas, &c.

In *Robinia* (*R. Pseudacacia*, commonly called the Acacia) the winter-bud is protected by three short, brown, triangular scales. On the young growing shoots the stipules are linear, subulate, and hairy. Ultimately they thicken and become woody, brown, persistent spines. They are less developed on the upper branches, where the need for protection is not so great. *Zizyphus Jujuba* is another case in which the stipules are spiny. Here also the two stipules are unequal, that on the upper side of the shoot being the longer.

Capparis also (*C. spinosa*) has two spines at the base of each leaf. As Colomb (19, 67) admits, they 'occupent exactement la même place que les stipules épines du *Robinia Pseudacacia.* Il n'est, dès lors, pas étonnant que l'on ait quelquefois considéré ces épines comme des stipules.' This, however, he disputes, because they are 'purement parenchymateuse,' a reason which, however, is by no means conclusive.

Azima, belonging to the exotic family *Salvadoraceæ*, is another genus which has spines at the base of the leaves.

Du Petit Thouars regarded the spines of the Orange as stipules, but they are now regarded, no doubt with reason, as aborted branches (19,1). Stipules in the form of spines also occur in *Ribes oxyacanthoides*, some species of *Bauhinia* (*B. grandiflora*), *Paliurus*, &c. These spines serve to protect the plant from herbivorous quadrupeds.

Spiny stipules in some cases serve to protect the plant in another and very curious manner. 'In the *Mimoseæ*,' says Bentham (20), 'spinescent stipules are met with in various groups, especially in the *Acaciæ Gummiferæ* and *Pulchellæ*, and a few *Phyllodineæ* and others, and, as far as has been observed, are always independent of physical conditions. In the *Acaciæ Gummiferæ*, whether from tropical America, Africa, or Asia, they offer the curious phenomenon of an extraordinary development of some of the pairs, or sometimes of nearly all of them, assuming the aspect of horns of cattle. Such horn-like enlargements are most general in dry, hot regions; but, as far as the information of collectors can be relied on, many of the specimens thus affected are from the richest moist forest regions of tropical America. They never appear to affect the whole of the stipules of any one bush, varying in degree of development in the several pairs of stipules of the same branch, but affecting special forms and tinges of colour, from an ivory-white to a livid purple, for each species.'

The Common Bulls-horn (*Acacia cornigera*), described by Belt (21), bears hollow thorns, while each leaflet produces honey in a crater-formed gland at the base, as well as a small sweet, pear-shaped body at the tip. In consequence it is inhabited by myriads of a small ant, which nests in the hollow thorns, and thus finds meat, drink, and lodging all provided for it. These ants are continually roaming over the plant, and constitute a most efficient bodyguard, not only driving off the leaf-eating ants, but, in Belt's opinion, rendering the leaves less liable to be eaten by herbivorous mammals.

Bower (22) describes another interesting case of a myrmecophilous plant—*Humboldtia laurifolia*. The stipules consist of two parts: a lower, sagittate part, with four to six glands on its upper face, and an ovate-lanceolate part, with one or more glands, on the lower surface; they originate from two outgrowths at the base of the leaf-stalk below the leaflets.

K. Schumann (23) figures the bladders, inhabited by ants, at the base of the leaves of *Duroia saccifera* and *Remijia physophora*, both tropical South American members of the family *Rubiaceæ*. He does not, however, regard them as stipules, but as 'sac-like outgrowths of the blade.' They lie at the base of the leaf, near the middle nerve.

In *Korthalsia* also, a Malayan Palm, the base of the petiole is swollen into a sort of ocrea, in which a species of ant makes its home.

Spiny stipules also occur in *Porlieria*, an American genus, a member of the family *Zygophyllaceæ*, in *Paliurus*, one of the *Rhamneæ*, &c.

NECTARIFEROUS STIPULES

Kerner was, so far as I am aware, the first who called special attention to the importance of extrafloral nectaries in the economy of plants. He, however, suggested that their function was to keep ants away from the flowers. The real object seems, rather, to be to attract ants, which, as already mentioned, protect the plant from various enemies—from caterpillars, leaf-cutting ants, &c. Every fruit-grower in Java knows how ants protect the plant from fruit-eating bats (*Pteropus*). Nectaries are often situated on the calyx, and the presence of ants protects the flowers from being bored through at the base by bees. Some species of *Smilax* also have winged petioles, in which ants make small nests.

As an illustration of glandular stipules may be mentioned those of the Vetch (*Vicia sativa*), which secrete honey, especially when the sun shines.

The stipular glands of *Viburnum* have been already described (*ante*, p. 40).

In the *Myrtaceæ*, again, we have cases of glandular stipules. In *Psidium Cattleyanum* they consist of one to four subulate processes, or of one rather membranous and colourless, trifid or tridentate piece. They scarcely seem to be protective, but the outer process is generally tipped with a globule of fluid.

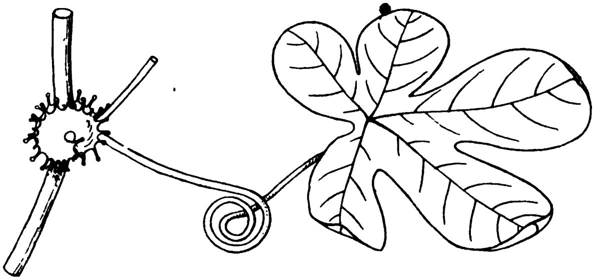

FIG. 312.—TROPÆOLUM CILIATUM, showing leaf and stipule. Nat. size.

The remarkable Peruvian species of *Tropæolum* already mentioned (*T. ciliatum*) has curious ciliated and apparently gland-tipped orbicular stipules (fig. 312).

Glandular stipules also occur in some *Lythrarieæ*, *Leguminosæ*, *Linaceæ*, *Onagrarieæ*, *Cucurbitaceæ*, *Droseraceæ*, Balsams and *Cruciferæ*.

AS AN ASSISTANCE IN CLIMBING

There are two ways in which stipules may assist in this respect, viz. (1) by being developed into tendrils, or (2) into more or less reversed spines.

The case of the tendrils of *Smilax* is one which has occasioned much discussion, but I agree with Tyler (24) that the embryological, together with the anatomical, characters indicate that in *Smilax* the tendrils are true stipules, found in connection with the sheathing petiole.

In *Paliurus australis* (fig. 313), a Southern European plant belonging to the same family as our Buckthorn, the stipules are spiny, but the two stipules of each leaf are different in form and serve for different purposes. Those on the upper side of the shoots are long, subulate, and straight; those on the lower side are shorter and deflexed. The former appear to serve as a protection against browsing quadrupeds; while the hooked ones also assist the plants to climb or scramble up among other shrubs and bushes.

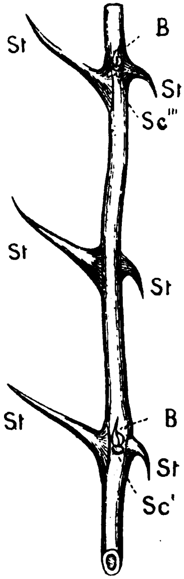

FIG. 313. — PALIURUS AUSTRALIS. PORTION OF A SHOOT.

St, *St*, spiny unequal stipules; *B*, axillary buds, the outer and longer scale of which is spiny; *Sc'*, scar of fallen petiole; *Sc'''*, the third scar in the order of arrangement, showing that the phyllotaxy is ½. Nat. size.

In *Machærium* also, a tropical American genus of

Leguminosæ, the stipules are often converted into thorns, which are in some cases bent backwards so as to aid the plant in climbing.

AS RESERVES OF NOURISHMENT

In *Gunnera*, according to Reincke (25), stipules serve as reserves of nourishment.

AS HOLDERS OF RAIN

Another use of stipules is to hold rain, as, for instance, in some species of *Thalictrum*, *Viola*, and *Polygonum*.

The leaflets of *Thalictrum* (*T. simplex*) are so arranged as to catch most of the raindrops; they are not wetted, however, by the rain, which runs off and down the petiole to the cup formed by the stipules. The stipules are fringed at the edge, which also assists to retain the moisture.

In some species of *Viola* also—for instance, *Viola tricolor* (Pansy) and the little yellow *V. biflora*—the leaf and leaf-stalk have a central furrow, down which the water runs to the stipules, by which it is retained.

The ocrea or sheath of the *Polygonaceæ* also serves in some cases for the same purpose. This is well seen in the large species, for instance, of *Rumex* and *Rheum*. They will retain water for several days after the rain has ceased. It is, however, gradually absorbed.

In support of this view I may refer to the case of the Teasel (*Dipsacus*), where the bases of the petioles are expanded and connate, thus forming a large cup, which generally contains water. It has been suggested by Kerner that this water forms a sort of moat, which protects the flowers from ants and other creeping insects. On the other hand, Mr. Francis Darwin suggests that insects, &c., are drowned in the water, and thus supply the plant with animal food. He has described certain curious protoplasmic threads, emitted by some of the cells, which he suggests may serve to absorb the nourishment thus supplied.

AS SUPPORTS

It is probable that, as Grevillius (26) has suggested, the ocrea of *Polygonum* may be of use in strengthening the stem at the internodes, which are points of rapid growth, and consequently of weakness. He observes that this can be tested by removing the sheath, and then shaking the stem, when it will be found that it is especially liable to give way at the internode.

CHAPTER VIII

ON THE NATURE OF STIPULES

In ordinary parlance, when we speak of a leaf we often think only of the leaf-blade. The leaf-blade is, however, in reality only part of the leaf. The complete leaf is generally described botanically—as, for instance, in Asa Gray's excellent 'Structural Botany,' Bentham's 'Handbook of the British Flora,' &c.—as consisting of (1) the leaf-blade, (2) the stipules, and (3) the petiole or stalk, to which I think, for reasons which will be presently given, we ought to add (4) the leaf-base. Vines (27) describes the leaf as divisible into three transverse parts — upper, median, and lower—corresponding to the blade, stalk, and base. The base may, he considers, be either more or less sheathing, or developed laterally, forming stipules.

The stipules, however, seem to occupy the same position in relation to the base as the blade or leaflets do to the stalk. If, therefore, the blade is considered as forming a division separate from the stalk, I should rather regard the leaf as consisting of four parts: the blade, stalk, stipules, and base.

Perhaps, however, the more philosophical view would be to regard the leaf as consisting of two parts—(1) the base, with or without foliar expansions, the stipules; and (2) the upper part or petiole, with or without a foliar expansion, the leaf-blade.

Sometimes all four divisions are present, as in the Rose; sometimes the stipules are absent, as in Maples; sometimes the leaf is sessile, the stalk, stipules and base being undeveloped, as in Gentians; sometimes the blade is absent, and its functions are performed by the flattened petiole, as in most of the Australian Acacias; sometimes the stipules perform the function of the leaf-blade, as in *Lathyrus Aphaca* (fig. 294).

That *Helianthemum vulgare* (fig. 22, p. 20) has stipules and *H. œlandicum* (fig. 23, p. 21) has none is clear and simple enough, but there are many cases in which the presence or absence of stipules is far from being so easy to determine, and which have been the subject of much difference of opinion amongst botanists.

For instance, the Composites generally (Daisies, Chrysanthemums, Dandelions, Lettuces, &c.) are said to be exstipulate, but in some the petioles are dilated at the base into appendages which can scarcely be distinguished from stipules.

In some Crucifers, as, for instance, in *Cardamine impatiens*, some of the lower leaves have rounded and thickened auricles, which in the upper leaves become prolonged into subulate, obtuse, falcate processes clasping the stem. These are often called stipules. They correspond to the auricles of other Crucifers which are continuous with the margin of the leaf.

The Umbellifers (Carrot, Parsnip, Parsley, &c.), again, have the petioles flattened and broad, often forming a sheath. In some the upper or smaller part of the sheath becomes detached. When this has proceeded sufficiently far the free lobes may fairly be called stipules. Indeed, it is obvious that there may be every intermediate gradation between a species with a merely flattened petiole and one with true stipules. Nay, such transitions may and do occur in the same plant, and even in the same bud.

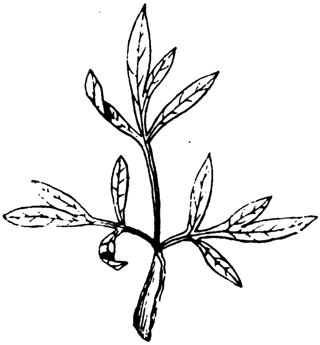

Fig. 314.—Leaf of Parsley.

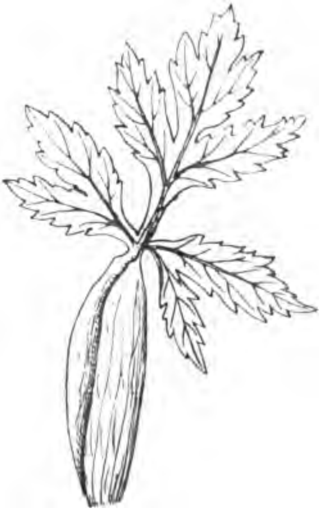

Fig. 315.—Leaf of Ostruthium.

I have figured leaves of three members of this family to illustrate this relation between leaf-sheath and stipule. In the Parsley (fig. 314) the sheath is quite entire; in *Ostruthium* (fig. 315) there is a distinct shoulder on each side; while in Fool's Parsley (*Æthusa Cynapium*) (fig. 316), a common British species, the shoulder has grown out into a small but distinct stipule.

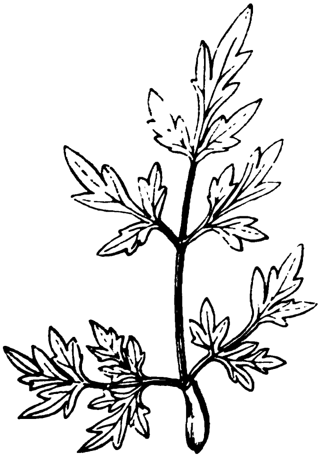

FIG. 316.—LEAF OF ÆTHUSA.

Speaking of *Canarium*, Bentham and Hooker say ('Genera Plant.,' i. 324): 'Folia exstipulata, vel pinnulis inferioribus sessilibus stipulæformibus, imparipinnata,' and again, 'Foliola infima *Canarii* interdum stipulas simulant' (p. 321).

The small primary leaves of the Mistletoe have been mistaken by some authors for stipules.

Aristolochia elegans, while really exstipulate, has a small cordate, membranous, subsessile leaf in the axil, which resembles a single axillary stipule; sometimes a pair are present. Close examination shows that this stipule-like process is really the first leaf of an axillary axis or bud. It clasps the main axis with its auricles, and has two buds in different stages of advancement lying between it and the petiole of the leaf in whose axil it occurs. The small leaf belongs to the larger and more advanced bud.

The early unfolding of the first pair of leaves of an axillary bud may often give the appearance of stipules. For instance, in Tutsan (*Hypericum Androsæmum*) the leaves are opposite and exstipulate, but the first two leaves of the axillary branch, before any further growth of the bud takes place, stand right and left above the base of each leaf, and by a careless observer may be taken for stipules.

The genus *Lotus* (Bird's Foot Trefoil) is quinquefoliate. The lower folioles have been sometimes regarded as leaflets, sometimes as stipules. Bentham and Hooker, in the 'Genera Plantarum,' say, 'Folia 4–5-foliolata, foliolis integerrimis 3 ad apicem petioli confertis, 1–2 juxta caulem stipulas simulantibus.'

Speaking of the corresponding organs in *Tetragonolobus*, Norman says that they 'par leur structure, leur coloration, leur forme et leur position, sont entièrement différentes des folioles, et s'harmonisent tout à fait avec les stipules que l'on trouve dans la plupart des Légumineuses ' (28).

The same may also be said of the allied genera *Dorycnium*, *Bonjeania*, &c.

Cambessèdes, however, maintains that the true stipules of *Lotus* and the other genera mentioned are two minute glandular elevations at the base of the leaf.

The *Leguminosæ*, to which these genera belong, are as a rule stipulate; so that if this view is correct we have an interesting case in which the stipules have dwindled away, and their function is performed by the lower leaflets, which have to some extent wandered away from their usual position in order effectively to take on this new duty.

Again, the tendrils of Cucumbers (*Cucurbitaceæ*) and *Smilax* have been regarded by some botanists as stipules, while this has been denied by others; and the same difference of opinion has existed with reference to the ligule of grasses.

I shall presently return to some of these doubtful cases.

Helianthemum guttatum is a very interesting species. As Dr. Stenzel (29) points out, the lower part of the shoots bears lancet-shaped leaves without stipules. Nearer the flower-buds the leaves tend to become smaller, and have stipules. These are linear, and attached quite at the base of the leaf. Frequently, however, leaves occur with only one stipule, while at the other side of the leaf is a tooth-like projection, into which a weak nerve enters, which is wanting on the other side of the leaf, or rather is replaced by the nerve of the stipule. In some cases there is no tooth, but the side of the leaf which has no stipule is broader than the other. Sometimes, again, there are no stipules, but the leaf has a tooth on each side, which may cut into the leaf almost to the base.

Stenzel therefore regards the so-called stipules of *H. guttatum* as being really leaflets. In that case, however, all the stipules of *Helianthemum* must be so regarded, and the case appears to be one which requires further study. The same argument might be advanced in the case of many undoubted stipules; *e.g.* Pansy.

There has also been a good deal of difference of opinion in the case of the Elders (*Sambucus*). In *S. canadensis*, Tyler (24) says that stipules are typically developed.

Bentham and Hooker ('Gen. Plant.' ii. 3) say, 'Petiolo basi nudo glanduloso v. foliolis stipulæformibus aucto.'

In our Common Elder (*S. nigra*) the leaves are sometimes exstipulate, sometimes (fig. 31, p. 26) have minute stipules; on the other hand, the Dwarf Elder (*S. Ebulus*) has small leaflets at the base of the leaf-stalk, which, in Bentham's words, 'look like stipules.'

In the Black Bryony (*Tamus communis*), there is at the base of the leaf a small cylindrical process, generally turned backward, which was regarded by Cauvet (30), and I think with justice, as a stipule. Colomb questions this, on the ground that these processes receive no nerves. As already mentioned, however, this does not seem to me a sufficient reason for excluding them from the category of stipules.

Norman also regards the axillary glands of *Cruciferæ* and *Lythrarieæ* as rudimentary stipules.

Another question which has been much debated is whether stipules are to be regarded as (1) dependent on leaves, as (2) autonomous and independent organs, or (3) as an integral part of the leaf.

As a supporter of the view that stipules are a dependence of the leaf I may quote Van Tieghem (31), who considered stipules to be leaf-lobes. He regarded every leaf with stipules as a compound leaf. Baillon (32) also quotes *Viburnum* as 'une bonne démonstration de ce fait que les stipules sont des lobes de feuille.' Richard also was of the same opinion. Schleiden appears to have doubted whether stipules had any claim to special significance. Asa Gray (33) describes stipules as 'appendages or adjuncts of a leaf,' and Bentham (34) as 'appendages at the base of the leaf-stalk.'

As a matter of fact, leaflets have, no doubt, often been taken for stipules.

However difficult the discrimination between leaflets and stipules may sometimes be, the real difference is well shown in species where the leaf-development is basipetal—that is to say, the upper leaflets are formed first, and the lower ones in succession. Now, if stipules were ordinary leaflets, they would in such cases be formed last, while, as a matter of fact, they make their appearance with, or even before, the first leaflets.

A strong reason against regarding stipules as mere subordinate structures dependent on the leaf-blade is that they arise so early, often, indeed, before the leaf-blade with which they are associated, as, for instance, in the Pea (fig. 26, p. 23), *Bucklandia* (fig. 190, p. 122), &c. A further reason against regarding stipules as mere dependent parts of the leaf is, that while in many cases leaves have no stipules, in others stipules take the place of leaves—using the word, that is to say, in the usual sense.

Thus, in *Lathyrus Aphaca* (fig. 304, p. 179) there are no leaflets, the leaf-blade being replaced by a tendril, and the ordinary function of the leaf-blade is performed by two enlarged stipules.

Again, in some species of *Adesmia* (fig. 311, p. 187), a South American leguminous genus, leaves are present only on the lower part of the long, straggling branches, the upper part bearing stipules only, which gradually pass into bracts.

It seems, then, incorrect to regard stipules as mere dependencies of the leaf-blade with which they are associated.

I now pass to the second view, that of those botanists—as, for instance, Lindley (35), Agardh (36), and Clos (37)—who have regarded stipules as autonomous organs, analogous to and independent of the leaf. Steinheil (4) maintained that each lobe was virtually a leaflet, and even a leaf. Turpin's opinion was that 'Les stipules caulinaires sont des feuilles distinctes, réduites à l'état rudimentaire' (39). In support of this view it has been urged that some plants have stipules but no leaves, and that in others the stipules appear early, often, indeed, it has been said, before the appearance of the leaf. This, however, is not strictly correct. No doubt they do often appear before the commencement of the leaf-blade, or of leaflets. In pinnate leaves the stipules are in some cases formed before the first leaflets. The rudiment of the leaf-stalk, however, as a rule appears before the stipule.

Another strong reason for regarding the stipule as a part of the leaf is the fact that the woody fibres which supply the stipules are, as a rule, if not always, derived from the foliar bundles. It has, indeed, been supposed that the *Rubiaceæ* and *Violaceæ* form an exception; but Colomb has shown that this is a mistake (19). Take, for instance, the case of the Pansy (*Viola tricolor*). The stipules (fig. 317, *S*) are large, more or less deeply laciniate at the sides. The central woody tissue of the stem (*T B*, fig. 318) sends out three fibres, *L*, *L* and *M*, which pass into the leaf-stalk. The two outer ones, *L* and *L*, soon branch, the larger division passing into the leaf, while the smaller one, *s*, supplies the stipule.

Fig. 319, representing a section of the stem of *Galium Aparine*, shows a similar arrangement: the foliar bundles, L, L, soon after leaving the central pith emit branches, S, S, which supply the stipules.

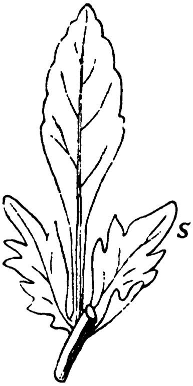

Fig. 317.—Leaf of Pansy. *S*, stipule.

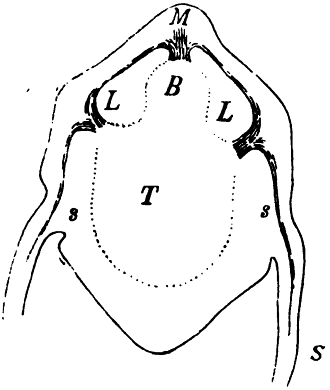

Fig. 318—Transverse Section of Stem of Pansy at a Node, showing leaf sage of vascular bundles into pas- and stipules (*S*).

Colomb defines stipules as appendages 'inserted on the stalk at the base of the leaf, the fibres of which are exclusively derived from the corresponding foliar bundles' ('inséré sur la tige, à la base de la feuille, et dont tous les faisceaux proviennent exclusivement des faisceaux foliaires correspondants').

But there are some undoubted stipules which contain no fibres, as Colomb himself says in another place, speaking of *Polygonum.*

The history of the early development of the young stipule shows, indeed, I think conclusively, that it cannot be regarded as a separate and independent organ. We must, then, I think, adopt the third view, viz., that stipules are an integral part of the leaf.

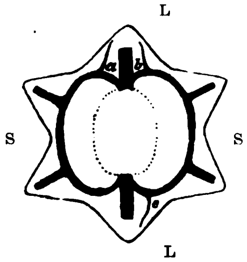

Fig. 319.—Transverse Section of Stem of Galium Aparine at a Node.

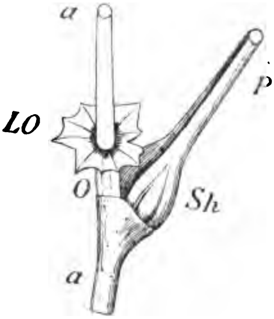

Fig. 320.—Plane (*Platanus orientalis*). Nat. size.
a a, axis ; *P*, petiole of leaf ; *Sh*, sheathing or concave base, covering the axillary bud ; *O*, ocrea ; *L O*, lamina of ocrea.

I now proceed to consider certain organs which must be included amongst stipules, although they diverge widely from the ordinary form and arrangement.

The Ocrea

The sheath or ocrea of the Planes, *Polygonum*, &c., is generally, and, I think, correctly, regarded as a form of stipule. In the Plane (fig. 320) the relations of the ocrea to the stem and the leaf-stalk have been well described by Colomb, from whose account the following figures are taken. Fig. 321 represents a section of the

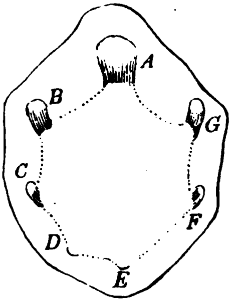

FIG. 321.

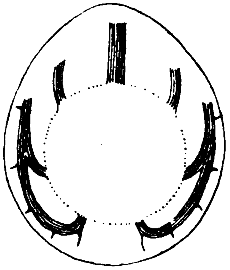

FIG. 322.

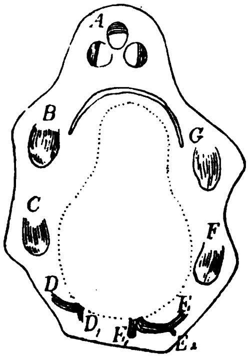

FIG. 323.

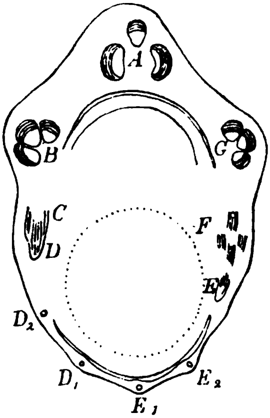

FIG. 324.

PLANE (*Platanus*).

twig a little below the joint, and shows seven woody fibres emerging from the central cylinder, which will enter the petiole. These may be termed 'foliar' fibres. The fibre *A* is first detached, then *B* and *G*, *C* and *F*, and lastly *D* and *E*, which are only beginning to emerge when *A* is already completely detached. The fibres as soon as they separate from the central cylinder

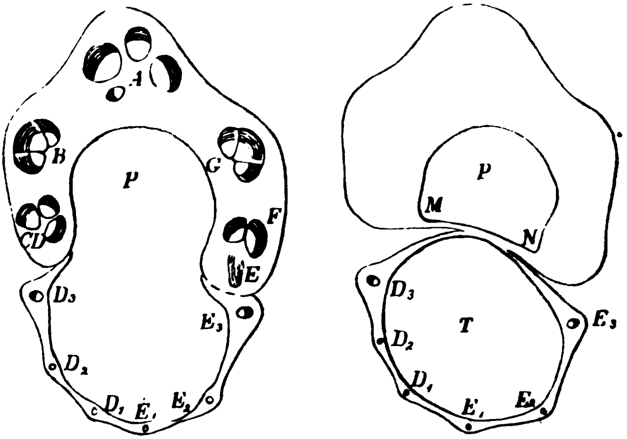

Fig. 325. Fig. 326.

Plane (*Platanus*).

bend towards *A* (fig. 322). A little higher (fig. 323) a slit appears, which is the commencement of the petiolar cavity in which the bud is sheltered. The main fibres, *D* and *E*, are approaching *C* and *F*, but have sent off lateral fibres, D' and E'. A little higher (fig. 324) *D* and *E* are still nearer *C* and *F*; at the lower part another slit has appeared—the commencement of the detachment of the sheath. Still a little higher (fig. 325) the petiole has detached itself from the sheath, but the two together have a single cavity. The fibres *D* and *E*, before entering the petiole, sent out several branches, D^1, D^2, D^3, and E^1, E^2 and E^3. Still higher we have the section shown in fig. 326. A parenchymatous band, *MN*, now separates the cavity of the petiole *P* from that of the sheath *T*, which encloses the stem. The sheath, therefore, is an appendage inserted on the node, and receiving fibres derived from the foliar fibres, before the latter have left the branch.

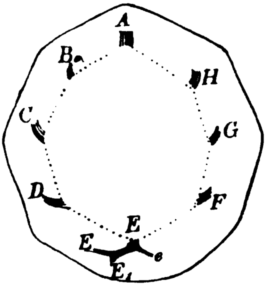

FIG. 327.

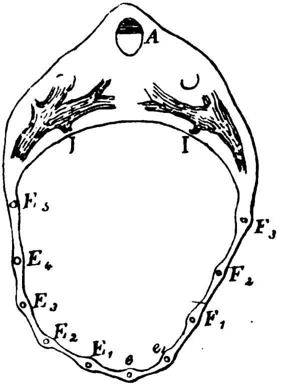

FIG. 328.

POLYGONUM LAPATHIFOLIUM.

The sheath of the Castor Oil plant (*Ricinus*) is constituted in the same manner, and, like that of the Plane, all its fibres are derived from the foliar bundles.

The stem of *Polygonum* (e.g., *P. lapathifolium*) is somewhat octagonal, with a central cylinder of the same form. Some little way below the leaf eight fascicles (fig. 327, *A* to *H*) detach themselves from the angles of the central octagon, and, passing outwards, turn towards the fascicle *A*.

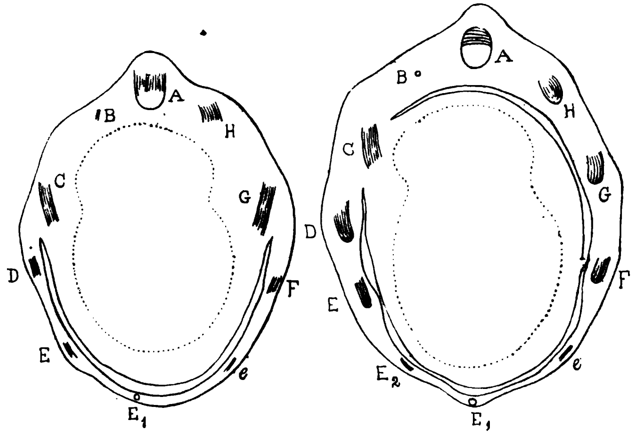

Fig. 329. Fig. 330.

Polygonum lapathifolium.

The fascicle *E* divides, each branch curving round towards *A*, and emitting as it does so a branchlet, E_1, *e*.

When the bundles have separated themselves from the central cylinder, and nearly reached the bark, a slit appears, which, passing from *C* to *G* (fig. 329), and gradually extending (fig. 330), finally separates the sheath entirely (fig. 331) from the central axis. The original

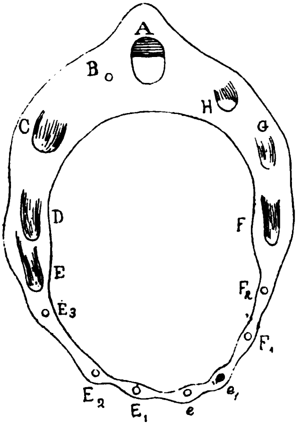

FIG. 331.—POLYGONUM LAPATHIFOLIUM.

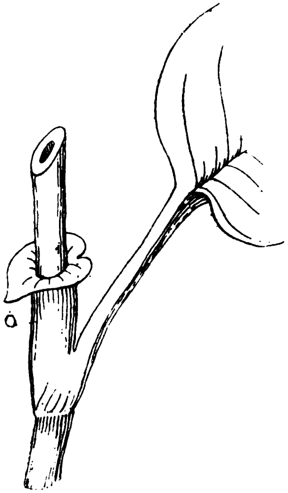

FIG. 332.—OCREA (O) OF POLYGONUM.

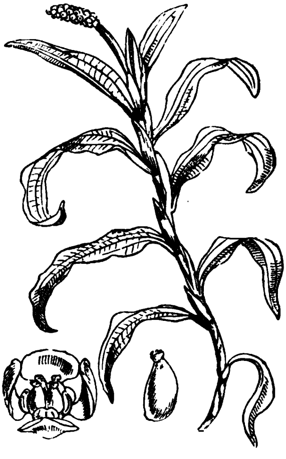

FIG. 333.—POTAMOGETON LUCENS.

fibres, *A* to *H*, are now (fig. 328) all collected in the part which will become the stalk of the leaf, the sheath being supplied by fibres thrown off from the branchlets. This sheath is known as an ocrea. Fig. 332 shows its natural position.

The development of the ocrea of the Pondweed (*Potamogeton*) (fig. 333) follows a very similar course.

Stipular Tendrils

In the Melon and other *Cucurbitaceæ* the tendril is regarded by some botanists as a stipule. This view is strongly supported by the fact that it is lateral, and that two tendrils occasionally occur, one on each side of the leaf. On the other hand, they are seldom at the same level, and the tendril is derived from a vascular bundle remote from that which produces the leaf. It is, moreover, separated from the petiole of the latter by buds. These considerations have led other botanists to regard the tendril as representing a leaf reduced to one or more of its nerves. The differences of opinion have been very remarkable. De Candolle and others have regarded them as stipules; Gasparini and Braun, as leaves; Link, as superfluous branches; others as abortive peduncles; others as roots. Payer has pointed out that when there is no tendril the leaf receives three fibro-vascular bundles. If there is a tendril, one goes to the tendril, and two enter the leaf; while, if there are two tendrils, each receives a bundle, and there is only one for the leaf. This supports the view that the tendril corresponds to a stipule.

The tendrils of *Smilax* will be referred to under the next heading.

MONOCOTYLEDONS

There has been much difference of opinion as to whether Monocotyledons have stipules. De Candolle stated without any hesitation or qualification that 'Les stipules n'existent dans aucune plante monocotyledone.' Others, however, have been of a different opinion. The tendrils of *Smilax* and the ligule of *Gramineæ* have been regarded by many botanists as true stipules.

The tendrils of *Smilax* arise in the same manner as stipules, being lateral outgrowths of the base of the young leaf. They must, I think, be regarded as stipules, though it will be seen from the subjoined note[1] that in this case, as in that of the Cucumber, there has been, and is still, much difference of opinion.

---

[1] The tendrils of *Smilax* have been considered as representing two lateral leaflets of a compound leaf by Von Mohl (*Ueber den Bau und das Winden der Ranken und Schlingpflanzen*, 41, 1827); Lindley (*Introd. to Botany*, Ed. 2, 118, 1835); Link (*Elém. Phil. Bot.* Ed. 2, i. 478, 1837); St. Hilaire (*Leçons de Bot.* 170 and 854, 1840); Le Maout (*Atlas de Bot.* 23, 1846), and Duchartre (Art. 'Vrille' in *Dict. Univ. Hist. Nat.*).

Mirbel (*Elém. de Physiol. et de Bot.* ii. 680, 1815); Treviranus (*Physiol. der Gewächse*, ii. 138, 1838); Seringe (*Elém. de Bot.* 175, 1841); De Candolle (*Théorie Elément.* Ed. 3, 321, 1844); Trécul (*Ann. Sci. Nat.* ser. 3, xx. 295, 1854), and Lestiboudois (*Bull. Soc. Bot. Fr.* iv. 745, 1857), believe these organs to be stipular. It is the opinion of Clos that they are neither leaflets nor stipules, but a double lateral prolongation of the cellulo-vascular elements of the petiole. Colomb (19, 33) regards the tendril of *Smilax* as a demi-ligule.

The ligule of grasses is another doubtful case, but must, I think, be regarded as a form of stipule.

The leaf of a grass may be divided into three parts—the sheath, the blade, and the ligule. The sheath embraces the stem; at the point where it terminates are two blades, one, generally called the leaf, making a broad angle with the stem, the other being a prolongation of the sheath, and known as the ligule.

It must, therefore, I think, be admitted that some Monocotyledons do possess stipules; and having regard to the great differences presented by the two classes, we cannot, I think, be surprised that the stipules of Monocotyledons generally differ considerably from those of Dicotyledons.

STIPELLÆ

The leaflets of pinnate leaves have sometimes a small foliaceous expansion at their base, and for these De Candolle proposed the appropriate name of 'stipels.'

Stipellæ do not, like stipules, run generally through a whole order, but are scattered sporadically in certain genera and small groups of genera. Fig. 334 shows an instance in a leguminous plant.

EFFECT OF REMOVAL OF LEAF

Goebel (9, 837), and subsequently Kronfeld (40), have made some interesting experiments as to the effect on stipules of removing the leaves belonging to them. In some cases, especially in the Bean (*Vicia Faba*) and Pea (*Pisum sativum*), the result was that the stipules were considerably increased in size; but in the majority of cases—Willow, Nettle, *Polygonum*, *Sida*, *Rosa*, *Rubus*, Clover, Chrysanthemum, &c.—no such effect was produced, and in the Apple sometimes only.

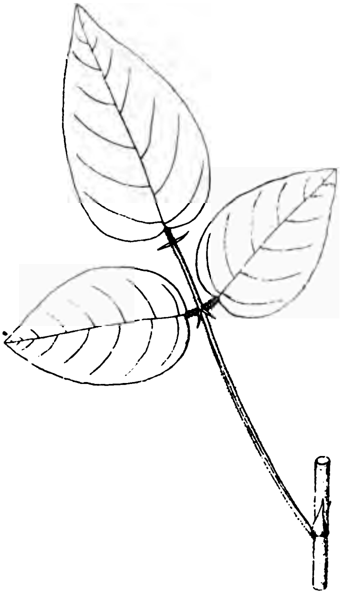

Fig. 334.—Leaf of Desmodium canescens, showing stipels at base of leaflets.

The following table gives the figures in one set of

Goebel's experiments. In each case two seeds of the same weight were sown together:—

		Normal Plant.	After Removal of Leaf
Plant 1.	Stipule of 1st leaf measured	141 mm.	239 mm.
	„ 2nd „ „	172 „	561 „
	„ 3rd „ „	165 „	920 „
Plant 2.	„ 1st „ „	92 „	98 „
	„ 2nd „ „	84 „	242 „
	„ 3rd „ „	107 „	351 „
	„ 4th „ „	86 „	276 „
	„ 5th „ „	68 „	361 „

It is probable, however, that more effect would be produced if the leaf had been extirpated at an earlier stage.

In other species no corresponding effect followed. The suppression of the stipules in *Lathyrus Aphaca*, for instance, had no effect in transforming the tendrils into leaf-blades.

Cotyledons very rarely have stipules. This may, perhaps, be because they are sufficiently protected by the fruit and seed coverings. There are, indeed, a few exceptions, as, for instance, in *Genipa clusiæfolia* (figs. 335–338), where, however, they are very small. They are interpetiolar, united into one ovate, acute piece, colourless and subscarious.

They occur also in *Psychotria* (fig. 339), another genus of *Rubiaceæ*, a family of which one of the most constant characters is the presence of stipules. Another instance is afforded by *Thelygonum*.

Clos, in an interesting and elaborate memoir (38), has attempted to show that as a rule bracts are modified stipules. De Candolle in 1858 expressed this opinion as regards *Begonia*; and Clos, amongst other species, refers to *Cinchona officinalis* and *angustifolia*, *Isertia coccinea*, *Berteria guianensis*, *Spermacoce calyptera*, *Cissus tamoides*, *Rondeletia obovata*, &c. Most of his references, however, are to old and somewhat vague figures. *Cinchona officinalis* has small but well-marked stipules at the base of the bracts, and the same is the case in *Rondeletia obovata*. If bracts really

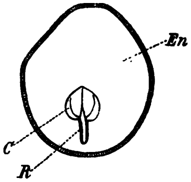

FIG. 335.

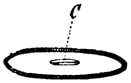

FIG. 336.

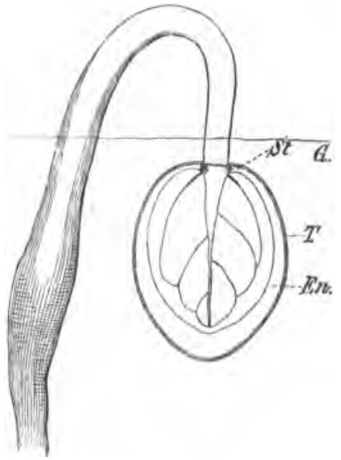

FIG. 337.

GENIPA CLUSIÆFOLIA.

FIG. 335.—Longitudinal section of seed, × 2½; *C*, cotyledon; *R*, radicle; *En*, endosperm.
FIG. 336.—Transverse section of seed, × 2½; *C*, cotyledon.
FIG. 337.—Germinating seed with side of seed and one cotyledon removed, × 4; *T*, testa; *En*, endosperm; *St*, stipule; *G*, surface of ground.

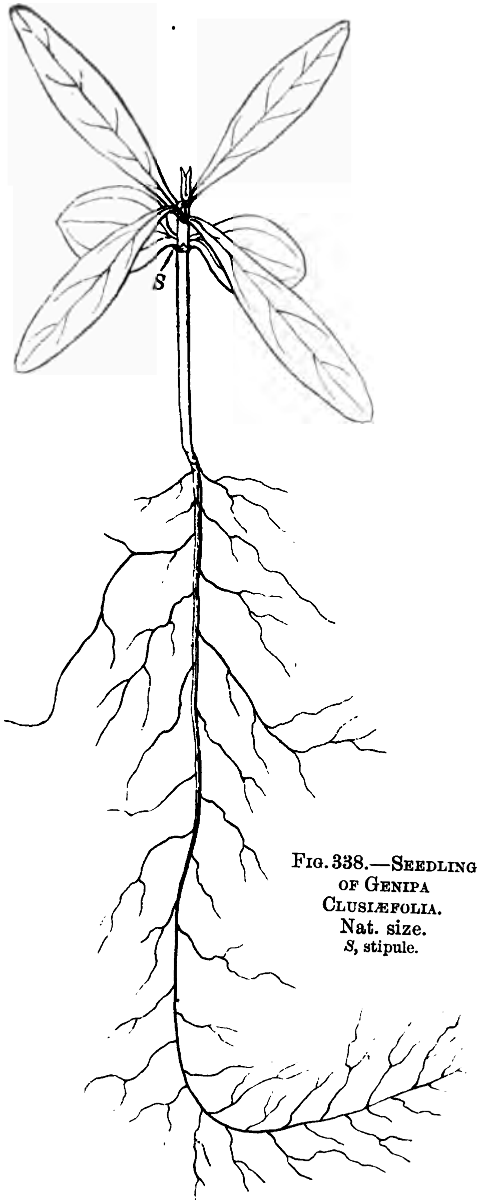

FIG. 338.—SEEDLING OF GENIPA CLUSIÆFOLIA.
Nat. size.
S, stipule.

represented stipules they would, as a rule, be in pairs, which is not the case. Moreover, Clos's view could not, of course, apply to the bracts of exstipulate species.

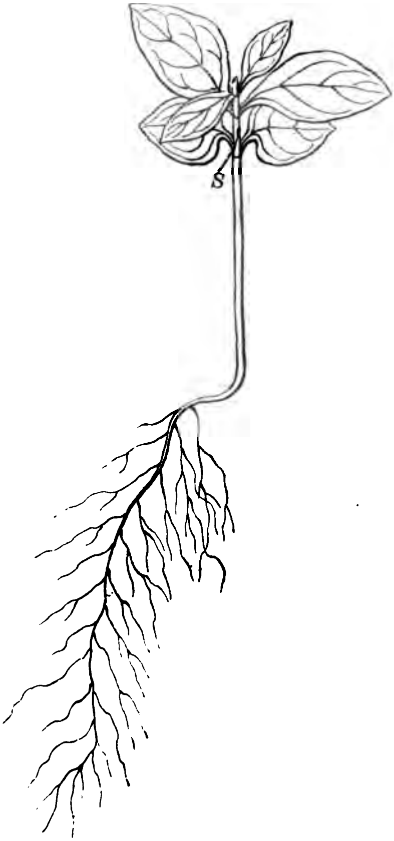

FIG. 339.—SEEDLING OF SPECIES OF PSYCHOTRIA. Nat. size.
S, stipule.

I think, then, as already stated, we must conclude that stipules are an integral part of the leaf; that leaflets are portions of the leaf-blade; and that, if we consider the leaf-blade as a part separate from the petiole, we must regard the leaf as consisting of four parts, viz.:

1. The blade.
2. The petiole.
3. The stipules.
4. The base.

Perhaps, however, it would really be more consistent with the facts to regard it as composed of two parts:

1. The upper part, or petiole, generally provided with a leaf-blade; and

2. The base, which also is often provided with a pair of stipules.

CHAPTER IX

SUMMARY

THE BUD

THE bud is a young shoot—that is, a stem or branch with its rudimentary leaves closely packed together. It is normally situated either at the summit of the stem or in the axil of a leaf.

The young leaves require protection against too great cold, heat, drought, or moisture, too vivid light, and the attacks of animals and plants. This is effected in various ways.

The scales which protect the winter-buds fall into at least eight categories:

1. Pedestals of last year's leaves, as in *Pyrus Aria.*
2. Stipules of last year's leaves, as in *Magnolia.*
3. In many cases the young leaves are protected by modified leaves, as, for instance, in Willows and Lilac.
4. In others the protection is afforded by leaf-stalks, the leaf not being developed, as in Maples and the Sycamore;

5. In others by the leaf-base, as in the Rose, Portugal Laurel, &c.;

6. In others, again, by stipules, as in the Beech, Oak, Elm, Poplar, &c. ;

7. In others by pairs of stipules, as in the Elm, Spanish Chestnut, &c.;

8. Or by two connate stipules, not, however, belonging to the same leaf, as in the Hop.

In many species the protection thus afforded is further enhanced (1) by the presence of a gummy or resinous secretion, as in the Horse Chestnut, Plane, Alder, Conifers; or (2) by furry hairs, as in the Plane, Horse Chestnut, Vine.

STIPULES

Stipules are normally more or less leaf-like structures at the base of, or just below, and one on each side of, the leaf-stalk. They are very variable in size and appearance.

A typical leaf may either be considered to consist of four parts:

1. The leaf base.
2. A pair of stipules.
3. The leaf-stalk or petiole.
4. The leaf-blade, which for shortness is often called the leaf.

Or, and perhaps more philosophically, of two parts:

1. A leaf-base, which may or may not develop stipules.

2. A petiole, the upper part of which normally expands into a leaf-blade.

In some cases, as in the Rose, all four are developed; in others one, two, or even three of these constituents may remain undeveloped.

As a general rule stipules serve to protect the bud, and in most cases shelter younger leaves only; but in some, especially in quickly growing plants, as, for instance, the Pea, Hop, Vine, &c., they envelop the petiole and blade of their own leaf.

In some cases the stipules of the last leaf of a year protect the young leaves of the following season, as, for instance, in some Magnolias, *Petteria*, Poplar.

In most cases, however, these stipules drop off, and the outer, covering scales are an integral part of the bud. Where there are stipules, the outer leaves often develop no leaf-blades (Oak, Beech, &c.).

When stipules serve, and serve only, to protect the bud, they are generally caducous, and drop off soon after the leaves have expanded.

In the Oak, Beech, Hornbeam, &c., each of these outer bud-scales is a single stipule.

In some cases, as in the Elm, Spanish Chestnut, &c., each consists of the two connate stipules belonging to the same leaf.

In others, as in the Hop, each scale consists of the two stipules on one side of the shoot. The two halves, therefore, belong to different leaves.

The general function of stipules being to protect the younger leaves, their presence or absence depends in great measure on the need for such protection. Hence we may almost lay it down as a general rule that where the leaf-stalk is broad and covers the bud there are no stipules, and that where it is too narrow to protect the bud stipules are present.

The protection of the bud is, indeed, the general function of stipules, though by no means the only one. We may summarise the uses of stipules as follows:

1. To protect the bud.
2. To help in performing, or even, as in *Lathyrus Aphaca*, to perform, the function of leaves.
3. Sometimes they are hardened into spines, and thus serve to protect the whole plant, as in *Robinia* (so-called Acacia).
4. Sometimes they form hooks, and assist the plant in climbing (*Paliurus*).
5. Sometimes they are developed into tendrils, as in *Smilax*.
6. Sometimes they secrete gum, which helps to protect the bud;
7. Or a sweet secretion, which attracts wasps, &c., as in some species of *Viburnum*.
8. Sometimes they serve to hold water, as, for instance, in some species of *Viola*, *Thalictrum* and *Polygonum*.

9. Sometimes they act as reserves of nourishment, as in *Gunnera*.

10. Sometimes they serve for a support to the stem, as in some species of *Polygonum*.

The view here suggested seems to apply well both to the cases where the stipules are very short-lived, and also to those in which they are very persistent. When they serve, and serve only, to protect the leaves to which they themselves belong, they often fall off when the leaves themselves expand. On the other hand, as a general rule, they protect the following leaf or leaves, as, for instance, in *Magnolia*, *Liriodendron*, and other *Magnoliaceæ*. When the stipules of the terminal leaves of one year protect the next leaves, which do not emerge till the following year, they are much more persistent than the leaves themselves. Both cases sometimes occur in the same family.

This, then, is the answer I should give to M. Vaucher's question (see p. 20), and the presence or absence of stipules is not determined, I think, as suggested by De Candolle, by any question of general symmetry, but rather by practical considerations connected with the wants and requirements of the plants.

No doubt, also, there are some cases in which stipules have ceased to be of any use to the plants, and are merely the persistent rudiments of organs which performed a useful purpose to the ancestors of the existing species in bygone ages, and under different circumstances.

THE FALL OF THE LEAF

Having traced up the leaf from its earliest rudiment, it remains, in conclusion, to say a few words about its final stages.

The fall of the leaf (41) is by no means a simple process or a mere case of death. In the first place, the chlorophyll-substance is too valuable to be lost and thrown away. Sachs[1] has satisfied himself that it passes out of the leaf, down the petiole, and thus migrates into the persistent parts of the plant, and is stored up for future use. With the general disappearance of the cell-contents the protoplasm and cell nuclei are dissolved, the chlorophyll corpuscles lose their normal outlines, the starch disappears, and the colouring matter changes, leaving in many cases a large number of small, bright yellow granules, to which the yellow tints of autumn are due. In many cases the cell-sap becomes bright red. Sachs has been able by chemical examination to follow the materials (and especially the starch), and also the most valuable chemical materials (especially the potash and phosphoric acid), down the petioles, into the twigs, where they are preserved, evidently to nourish the growing buds of the following spring.

While these changes are taking place a new layer of cells is formed across the base of the petiole (fig. 340).

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[1] *Flora*, 1863, p. 300; *Phys. of Plants*, tr. by H. M. Ward, p. 318.

These cells eventually adhere less and less closely together, so that at last the slightest touch or the gentlest wind brings the leaf to the ground. That this is not a mere case of death of the leaf, but, on the contrary, is a vital process, we may easily convince ourselves by breaking a branch during summer. In that case it is killed, the new layer of cells is not formed, and the leaves remain firmly attached to the twig.

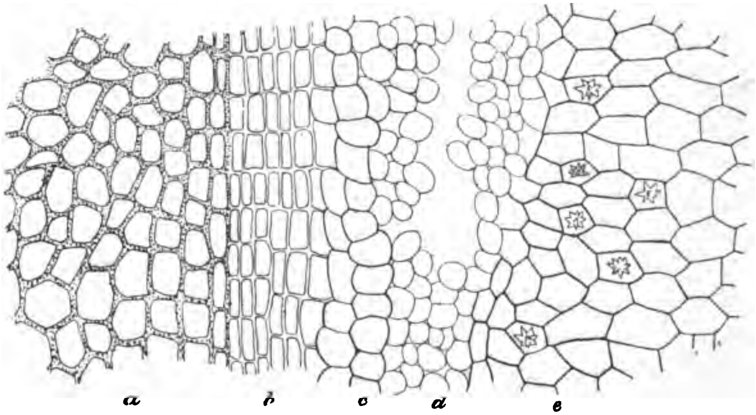


Fig. 340.—Longitudinal Section through the Junction of Stem and Leaf of the Horse Chestnut in Autumn.

a, parenchyma forming the outer cortex of the twig; *b*, external cork layer of the same; *c* and *e*, parenchymatous tissue at the base of the leaf-stalk; *d*, separating layer, the continuity of which is already broken in the upper part.

It is also of interest to notice how plants utilise the fact of the temporary nature of their leaves. Leaves share with the bark (also transient) the functions of the excretory organs of an animal. In their cells are deposited the waste products of the chemical life-processes, to be got rid of when the leaf falls or the bark peels. A leaf which has served its time and then been dropped contains quantities of calcium oxalate, resinous and gummy matter, and, like the bark also, alkaloids, such as nicotin, thein, and other nitrogenous excreta.

Climate has, naturally, a great influence on the length of time during which leaves remain attached. Where autumn is prolonged the leaves also last long. Thus, for the neighbourhood of Naples, excepting when winter sets in unusually early, Tenore quotes the end of November for the leaf-fall of the Walnut, Ash, Lime, Oak, and Poplar, and states that the leaves of the Apple, Beech, Elm, and Birch often last till the end of December, and the Cherry is evergreen. Foliage generally will keep longer in a damp, sheltered spot than in dry, sunny, exposed positions, and longer after a wet than a dry summer. Trees do not lose their leaves at the same time: not only are Oaks and Elms still green when the Horse Chestnuts and Limes are almost bare, but some individual trees retain their leaves longer than others of the same species. Apart from conditions of climate or weather, each species has its own peculiarity in this regard. This may sometimes be due to the fact that species now growing together in one country have come originally from somewhat different climates. A plant may have contracted the habit through long generations of shedding its leaves early or late, as the case may be, and retain the habit under changed conditions. De Candolle explains early leaf-fall in some cases by introduction from an extreme climate where it would be necessary, and instances the Walnut, introduced from Armenia.

Another question is, Do the plants which come into leaf early in spring lose their leaves early in autumn, and are the late leafers also tardy as regards defoliation? Or are the early leafers late to lose their leaves? The hawthorn hedges are among the first to show signs of green in the spring, and among the last to lose their foliage in the autumn. The Horse Chestnut buds have burst when the Oak and Ash are grey as at midwinter, but the latter retain their leaves the longer. We must remember, too, that the Ash gets its flowering over before leafing, while in the Chestnut the leaf-buds are the first to expand. To try and settle this point De Candolle made a *résumé* of four years' observations in Belgium, in which twenty-eight species or varieties were concerned. He made four lists: A, the early leafers; B, those with an early leaf-fall; C, late leafers; D, those where the fall is late. Each list contains about thirteen names. Two, *Spiræa sorbifolia* and Lilac, are common to A and B; that is, out of thirteen early leafers only two lose their leaves early. Four are common to A and D: leaf early but fall late. Two, Walnut and *Gleditschia ferox*, occur in both B and C, having an early fall, though leafing late; and four are late in leafing and have also a late leaf-fall. It is therefore evident that the time of leaf-fall does not depend on the time of bursting of the buds. De Candolle also quotes observations on individual trees. In many species, like Horse Chestnut, Beech, Elm, &c., trees growing side by side, planted at the same time, and subjected to the same external conditions, neither come into leaf nor lose their leaves simultaneously. These facts of idiosyncrasy, he says, are constant. They recur in the same manner year after year, even when the differences in time are only three days. Of three old trees in the court of a country house at Frontenex, the owner stated that for years they followed the same order of succession at both epochs : those which were first to leaf were also the earliest to lose their leaves. A Chestnut in the gardens of the Tuileries from its habit of early leafing is known as the *Vingt Mars*; and M. Henri Vilmorin states that, compared with the other Chestnuts in the gardens, it keeps its leaves beyond the mean time of leaf-fall. M. Vilmorin also observed thirty-four Horse Chestnuts, 150 years old, in a plantation on his own property at Verrières in 1876 and 1877. He found that those which were the first to lose their leaves in 1876 were in the same category next year, with slight differences as to order. Six of those which were the first to put out leaves in spring were late to lose them in autumn, while five others were early in leaf and early in losing leaf. He concludes that the two phenomena have no regular relation. Similar observations on the Beech and Elm led to the same conclusion.

Evergreen leaves differ greatly in length of life. Some remain on the tree for several years; for instance, in the Scotch Fir, three or four years; the Spruce and Silver Fir, six, seven, or even eight; the Yew, eight; *Abies Pinsapo*, sixteen or seventeen; *Araucaria*, even longer. It is true that during the later years they gradually dry and wither; still, being so long-lived, they naturally require special protection. They are, as a general rule, tough, and even leathery.

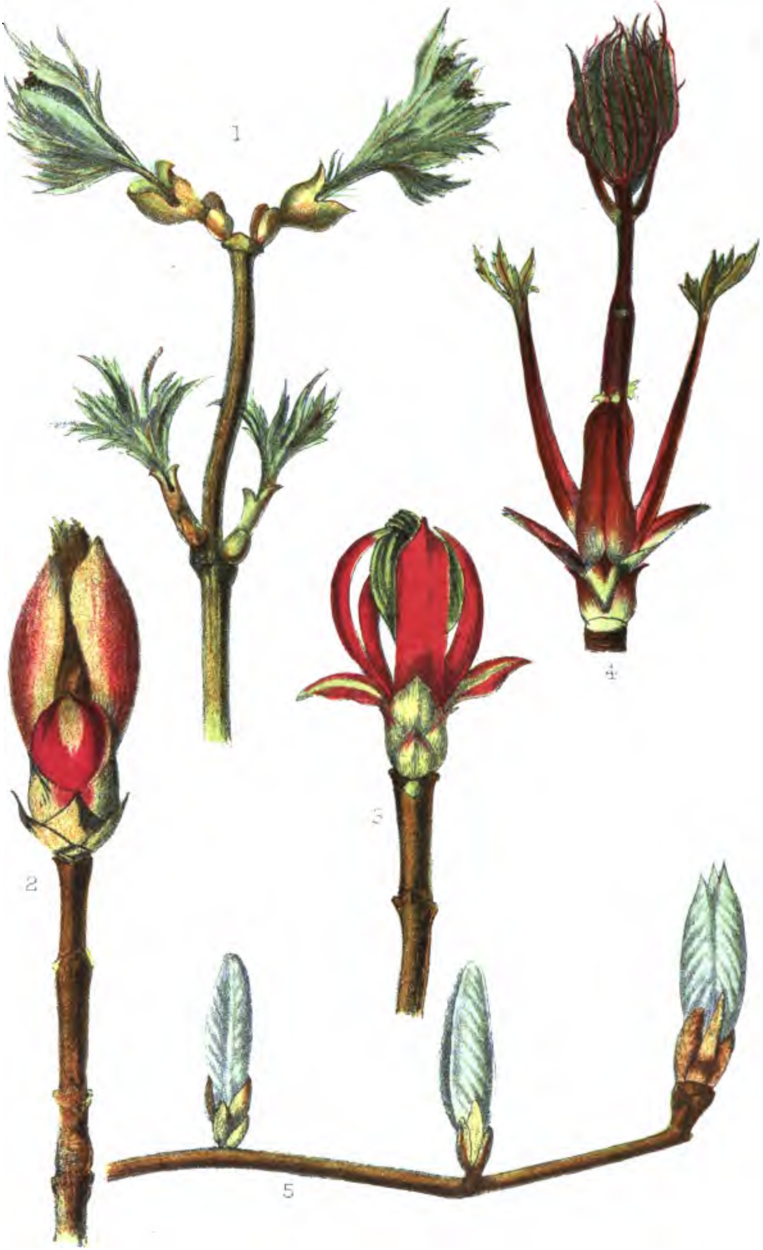
Thus, then, I have endeavoured to answer Vaucher's question—to explain, at any rate, in some cases the presence, the uses, and the forms of stipules, and the structure of buds in some of our common trees, shrubs, and herbs.

If I shall have induced any of my readers to look at them for themselves in the coming spring they will, I am sure, be amply rewarded.

They will often be reminded of Tennyson's profound remark about Nature:

> So careless of the single life,
> So careful of the type she seems,

and will be more and more struck with wonder and admiration at the variety and beauty of the provisions by which Nature preserves these tender and precious buds from the severity of winter, and prepares with loving care and rich profusion for the bright promise of spring and the glorious pageant of summer.



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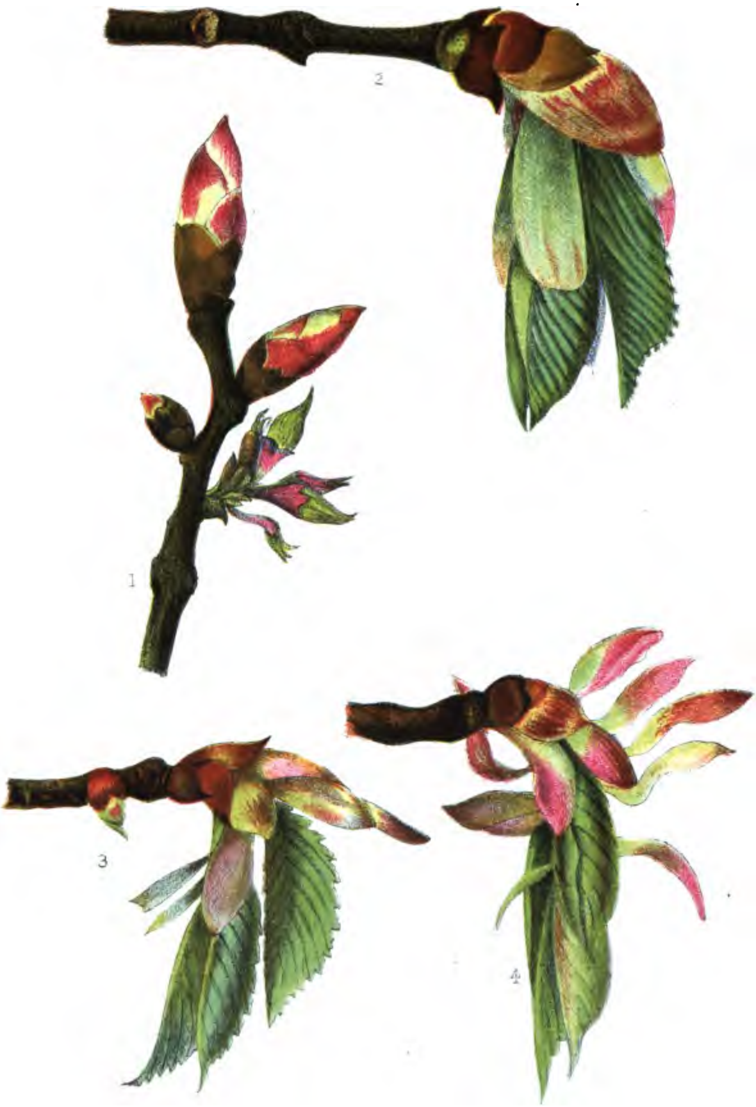

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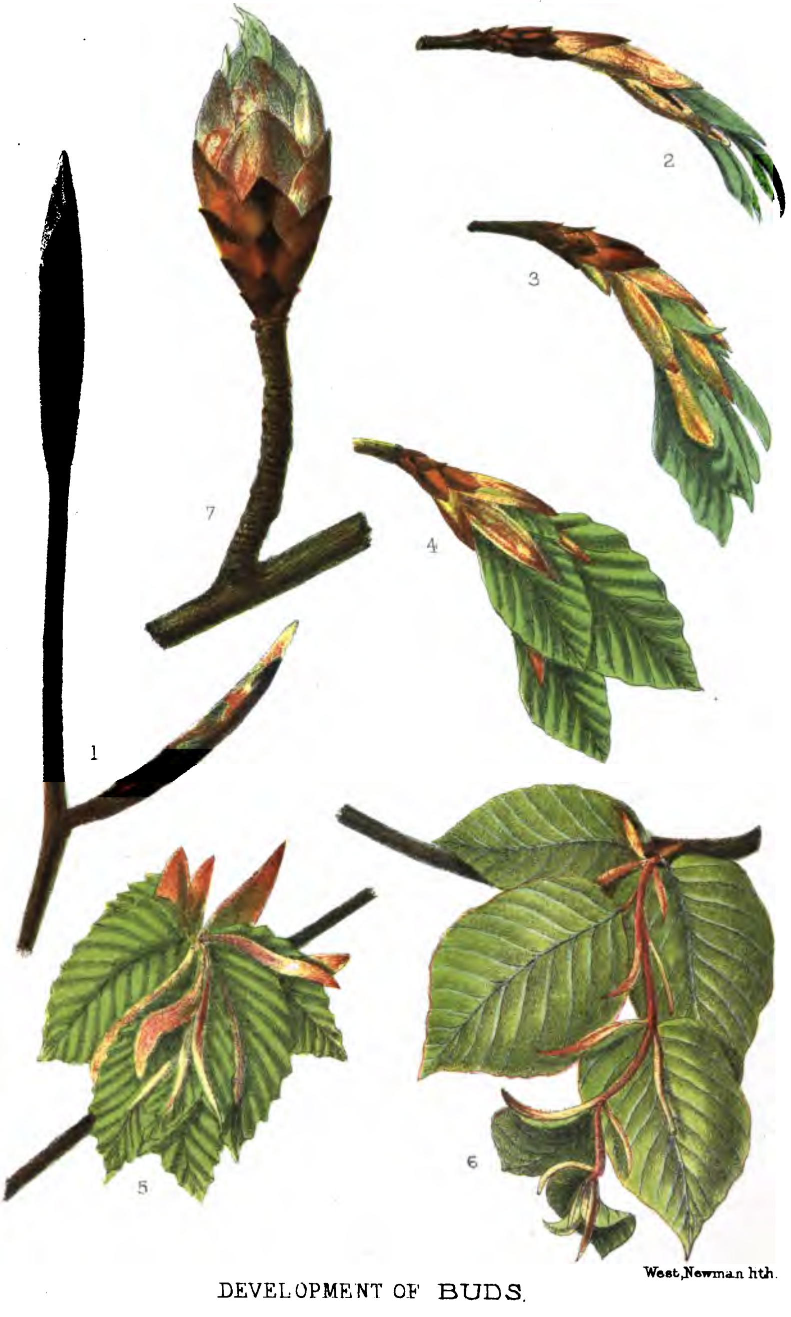
DEVELOPMENT OF BUDS.



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